3.0 CTSS PILOT STUDY RESULTS AND MAJOR FINDINGS

Study results for the six months of pilot studies conducted on the CTSS pilot facility have been summarized below for information during the screening, optimization and demonstration phases of testing, respectively.

For the demonstration data results, more detailed discussions are provided related to phosphorus removal rates through the pilot unit and also for residual solids characterization and dewatering, bioassay testing and low level mercury assessments. Detailed discussions related to all Standard of Comparison water quality data obtained during the demonstration testing is also provided.

3.0.1 Phosphorus Forms Tested and Reporting Conventions

In all, three distinct forms of phosphorus were analyzed during the CTSS studies. A brief summary of the three forms are provided below:

- ***Soluble Reactive Phosphorus (SRP)***

  Upon collection, samples are prepared in the field by filtering through a 0.45 micron filter and placing in an unpreserved sample bottle. Upon receipt in the laboratory, a direct colorimetric analysis is conducted without any sample digestion. The analytical result from this test is defined as the SRP content and typically represents the ortho phosphorus fraction and a small portion of the condensed phosphorus that is unavoidably hydrolized during the analytical procedure. Soluble Reactive Phosphorus results are described below using the acronym "SRP" and the data is all reported on an elemental phosphorus weight basis (*i.e.,* mg/L or μg/L as P).

- ***Total Dissolved Phosphorus (TDP)***

  Upon collection, samples are prepared in the field by filtering through a 0.45 micron filter and then preserving the sample to pH 2 or less using sulfuric acid. In the laboratory, the sample is digested using strong acid solutions converting all of the phosphorus forms contained in the sample to dissolved orthophosphate. Total Dissolved Phosphorus results are described below using the acronym "TDP" and the data is all reported on an elemental phosphorus weight basis (*i.e.,* mg/L or μg/L as P).

- ***Total Phosphorus (Total P)***

  Upon collection, the samples are immediately chemically preserved to a pH of 2 or less using sulfuric acid. In the laboratory, the sample is digested using strong acid solutions. The objective of the Total P analysis is to obtain the Total P of the sample regardless of the form (*e.g.*, reactive, dissolved, etc.). Total P results are described below using Total P and this data is all reported on an elemental phosphorus weight basis (*i.e.,* mg/L or µg/L as P).

3.0.2 South Test Site (Post-STA) General Water Quality Characteristics

The variation of Total P in the raw water supply of the South (Post-STA) Test Site during the study period is shown in **FIGURE 3.1.** Total P at the South Test Site generally ranged from between 15 to 30 micrograms/liter (µg/L) during the entire study period (June through December, 1999). The average Total P concentration recorded at the South Site was equal to 22.4 µg/L during this time, and elevated Total P data was only observed during the September time period as shown in **FIGURE 3.1**. Total P spikes as high as 70 µg/L were observed during this time and were attributed to the release of high concentrations of particulate phosphorus attributed to the SAV harvesting activities which were occurring upstream of the CTSS intake structure. SAV harvesting was performed in order to transplant SAV from the ENR into the newly flooded Cell 5 of STA 1 West.

Based upon the average monthly data shown in **FIGURE 3.2**, the SRP component of the Total P at the South Site was typically quite low and represented less than 20 percent of the total. The SRP was, in actuality, even lower than shown in **FIGURE 3.2** as all SRP data reported by the laboratory to be less than 2 µg/L were averaged as if they were 2. **FIGURE 3.2** also provides a summary of the dissolved phosphorus data and shows the TDP content of the South Site ranging from approximately 66 to as high as high as 87 percent of the Total P content.

In general, the ENR effluent, or South Test Site, water quality observed during the CTSS study period can be characterized as a highly colored water (derived naturally from area muck soils) possessing an approximate neutral pH, relatively high total dissolved solids (TDS) (exceeding drinking water standards), and containing relatively high concentrations of total organic carbon (TOC). Representative analytical values observed during CTSS testing for select parameters at the South Test Site are provided below:

Parameter	South Site Average Value	Range
pH, pH units	7.1	6.5 – 7.6
Color, PCU	113	89 – 144
TDS, mg/L	581	524 – 688
TOC, mg/L	29	13 – 37

3.0.3 North Test Site (Post-BMP) General Water Quality Characteristics

The variation of Total P in the raw water supply of the North (Post-BMP) Test Site during the study period is shown in **FIGURE 3.3**. The Total P content of the North Test Site generally ranged from between 110 to 160 μg/L during the entire study period (October 26 through December 23, 1999). The average Total P concentration recorded at the North Site was equal to 149 μg/L.

Based upon the average monthly data shown in **FIGURE 3.4**, the SRP component of the Total P at the North Site varied considerably and ranged from 39 to as high as 71 percent. **FIGURE 3.4** also provides a summary of the dissolved phosphorus data and shows the TDP content of the North Site ranging from approximately 59 to 82 percent of the Total P content.

Representative analytical values observed during CTSS testing for select parameters at the North Test Site are provided below:

Parameter	North Site Average Value	Range
pH, pH units	6.8	6.2 – 7.5
Color, PCU	145	114 – 236
TDS, mg/L	308	278 – 343
TOC, mg/L	18	4.5 – 30

3.1 SUMMARY OF SCREENING TEST RESULTS

The screening phase investigation consisted of a total of 28 tests performed from June 3, 1999 to September 26, 1999. **TABLE 3.1** shows the test conditions and the resulting filtrate Total P concentration of each screening phase trial. Each trial was conducted for several days as shown in **TABLE 3.1**. **FIGURE 3.5** provides a schematic diagram of the pilot facility and shows the various process units used during the screening tests.

The screening phase investigation consisted of a total of 28 tests performed from June 3, 1999 to September 26, 1999. **TABLE 3.1** shows the test conditions and the resulting filtrate Total P concentration of each screening phase trial. Each trial was conducted for several days as shown in **TABLE 3.1**.

Two essentially identical conventional water treatment trains were used during the testing at the South Site with each train containing 1) an in-line static mixer, 2) an extended time coagulation tank, 3) two flocculation tanks in series, 4) a clarifier fitted with inclined plate settlers,; and 5) granular media rapid filters in parallel. The chemically treated (and clarified) water could be introduced to any one or all of the filter columns. Various chemical tested included 1) alum ($Al_2(SO_4)_3$)•14 H_2O, 2) ferric-sulfate ($Fe_2(SO_4)_3$); 3) anionic coagulant aid (A-1849 polyacrylamide also known as PAM); and 4) hydrated lime ($CaOH_2$).

Filtration tests were conducted with 1) anthracite; 2) expanded shale; 3) sand; 4) granular activated carbon (GAC); and 5) 'Polystyrene' granular filter media. Both up and downflow filtration modes were performed. Three filtration methods were tested, which were 1) downstream controlled 'suction' filtration; 2) downstream controlled gravity filtration; and 3) declining rate gravity filtration. Besides the conventional treatment process, direct in-line filtration and direct filtration processes were investigated as well. The clarification process was tested at four distinct surface loading values from 0.14 gpm/sq.ft. to 0.71 gpm/sq.ft. Hydraulic filter loadings were investigated in the range of 2.9 gpm/sq.ft. to 6.3 gpm/sq.ft. Actual clearwater filter headlosses were measured regularly and contrasted to theoretical headloss values.

A description of the three different filter hydraulic control techniques used the screening phase is provided below:

1) ***Downstream Controlled Suction Filtration (Tests 1, 3, and 4)***

   Each filter unit consisted of the filter column, a centrifugal pump, and a flow meter device. Both the pump and the flowmeter were located downstream of the filter. A 4-20 mA flowmeter signal output and the preset value of the target flow provided a feedback system for the control of the variable rate pumping.

2) ***Downstream Controlled Gravity Filtration (Tests 5, 6, 7, and 9)***

   A manually operated control valve was located downstream of the filter. The intended initial hydraulic loading of a filter could be generally achieved at a partially restricted valve position. The manual opening of the valve provided an essentially constant filtration rate after the filter is put into operation. Upon reaching the fully open position of the valve, the filtration rate could not be maintained resulting in a decline of filter throughput. In summary, the downstream controlled gravity filtration is a quasi-constant rate followed by a declining rate filter operation.

3) ***Declining Rate Gravity Filtration (Tests 11, 13, 15, 17, 19, 21, 23, 24, 25, 26, 27, and 28)***

A manually operated control valve was located downstream of the filter. The initial hydraulic filter loading of 1.3 x Q (where Q is the intended throughput) was adjusted at a partially restricted position of the control valve. The initially adjusted valve position was maintained resulting in a monotone declining rate filtration rate throughout a filter run. A filter run was typically terminated when the actual hydraulic filter loading has declined to about 60 percent of the intended value (0.6 x Q).

Direct in-line and direct filtration tests were also conducted during the screening phase and a brief description of the specific testing protocols used for each of these is provided below:

- ***Direct In-line Filtration***

  The coagulant and coagulant aid, if applied, are dosed prior to the coagulation process. After coagulation, which is generally achieved by static mixing the chemically pretreated water is introduced directly to the granular filter units. While some flocculation may take place in the conduits, conventional flocculation in agitated chamber(s) and a clarification process are excluded from the direct in-line filtration process. The precipitated aggregates are relatively small in size and often referred to as "pinflocs."

- ***Direct Filtration***

  The treatment chemicals are dosed to the raw incoming water. After coagulation and flocculation, the chemically pretreated water is introduced directly to the granular media separation process. In other words, clarification is not used in a direct filtration process. As a result of the absence of clarification, mass filter loading values typically exceed those accounted for in conventional treatment processes. Screening phase tests typically utilized a static mixer for coagulation and a single stage flocculator chamber for flocculation.

Used throughout the discussion of results are the following reporting conventions:

- Clarifier surface loadings are reported in terms of a gallons-per-minute per-square-foot (gpm/sq.ft.) unit based on a projected lamella area; and

- Reported dosage concentrations of alum and ferric-sulphate process chemicals are based on a metallic equivalent (*e.g.,* 20 mg/L alum always refers to a dosage of 20 mg/L alum as Al).

A tabular summary of the results for the individual screening tests is provided in **TABLE 3.1 - Screening**. Results are described below:

TRIAL 1 (days 1 to 6):

Baseline testing was completed using all unit processes with no feed chemicals followed by a granular filtration process. After passing through the flocculator tanks and the clarifier, the settled raw water was distributed to the six filters. The hydraulic detention time (HDT) in a single flocculator cell varied from 17 to 20 minutes. The surface loading rate to the clarifier was 0.43 gpm/sq.ft. based on the 28 ft^2 projected lamella area. *Downstream controlled 'suction' filtration* was utilized to achieve the hydraulic filter loading of 4.9 gpm/sq.ft.

As shown in **TABLE 3.1**, approximately 30 percent of Total P was removed through clarification; however, little or no Total P was removed by any of the filters. During this baseline period of operation, clean water headloss was determined for each of the filter medias and all pumps, flow meters and mixing equipment were calibrated and tested. Details of the clean water headloss calculations may be found in **APPENDIX 3** in the handouts provided at the second Technical Review Team meeting.

TRIAL 2 (days 1 to 6):

Trial 2 investigated the Total P removal efficiency of the clarification process at relatively high hydraulic loading rates. After the introduction of 12 mg/L alum ($Al_2(SO_4)_3$), the coagulant was dispersed by means of an in-line static mixer. Energy (mixing) input was applied by means of mechanical mixers in the three, flocculator chambers that were operated in series. The HDT varied from 10 to 13 minutes in a single flocculator cell. The intended clarifier surface loading was

0.71 gpm/sq.ft. Process solids were at a rate of 1.2 to 1.5 percent of the unit throughput. The clarified water was wasted bypassing the filter columns.

Testing results suggest that at the applied conditions, limited or no Total P removal was achieved by the clarification process alone under the specified conditions.

TRIAL 3 (days 7 to 15):

Chemical coagulation and polymer addition, to enhance settling, followed by filtration was investigated in the third trial. The two treatment chemicals were alum ($Al_2(SO_4)_3$) coagulant, and A-1849 polyacrylamide coagulant aid. A-1849 polymer is manufactured by Cytec Chemical Corporation. The targeted alum dosage was 12 mg/L. The anionic polymer was dosed at a concentration of 0.5 mg/L. While alum was introduced upstream of the static mixer, the polymer was applied just downstream of flocculator tank #2.

The clarified water was distributed to Filters 1A, 1B, and 1C. Targeted clarifier surface and hydraulic filter loadings were 0.43 gpm/sq.ft. and 4.9 gpm/sq.ft., respectively. HDT in a single flocculator cell varied from 16 to 18 minutes. *Downstream controlled 'suction' filtration* was applied.

Analytical results suggest that approximately 40 percent of Total P could be removed by clarification and the average Total P concentration of the clarified effluent was equal to 11.3 μg/L. The 'Swiss' dual media filter configuration, utilizing expanded shale and sand media, demonstrated that under the conditions tested Total P concentration could be reduced below the threshold 10 μg/L level. During this trial, the average Total P content of the 'Swiss' filtrate was equal to 8.2 μg/L.

TRIAL 4 (days 7 to 15):

Testing included the use of the ferric-sulfate and calcium hydroxide. Ferric-sulfate ($Fe_2(SO_4)_3$), was dosed at 3.5 mg/L and the hydrated lime was applied at a target concentration of 40 mg/L. As a result of both the natural alkalinity of the raw canal water and the application of the lime, the pH was typically raised to about 9. While ferric-sulfate was introduced upstream of the static mixer, hydrated lime was dosed directly into flocculator tank #1.

The clarified water was distributed to Filters 2A, 2B, and 2C and the clarifier surface and hydraulic filter loadings were 0.43 gpm/sq.ft. and 4.9 gpm/sq.ft., respectively. HDT in the flocculator cells varied from 15 to 17 minutes. *Downstream controlled 'suction' filtration* was applied.

Under the conditions tested, there was virtually no Total P removal in the clarifier as the average Total P influent concentration was equal to 17.7 μg/L and that of the clarifier effluent was 17.2 μg/L. Approximately 30 percent of Total P was removed through filtration and the lowest average Total P of 12.3 μg/L and was produced by the 'Wahnbach' media.

TRIAL 5 (days 16 to 19):

In the presence of both a coagulant and a coagulant aid, Total P removal efficiencies of clarification and granular media filtration were investigated. The applied treatment chemicals were alum and A-1849 polyacrylamide. The alum dosage was 10 mg/L and the anionic polymer was dosed at 0.5 mg/L. While alum was introduced upstream of the static mixer, the polymer was applied just downstream of flocculator tank #2. The clarified water was discharged to Filters 1A, 1B, and 1C. The granular filters were operated in the *downstream controlled gravity filtration* mode. Targeted clarifier surface and hydraulic filter loadings were 0.43 gpm/sq.ft. and 6.0 gpm/sq.ft., respectively. HDT in a single flocculator cell varied from 17 to 20 minutes.

Approximately 40 percent of the influent Total P was removed by clarification. Filtration removed an additional 20 to 30 percent Total P in this trial. Filtered effluents produced average Total P data of less than 10 μg/L in both 'LA' (9.8 μg/L) and the 'Swiss' (8.0 μg/L) filter columns, respectively.

TRIAL 6 (days 16 to 19):

In the presence of both a coagulant and a pH-adjusting agent, Total P removal efficiencies of clarification and granular media filtration were investigated. The applied treatment chemicals were ferric-sulfate and hydrated lime. The dosage of ferric-sulfate was 1.5 mg/L. The targeted dosage concentration of hydrated lime was 50 mg/L, which raised the effluent pH to about 9. While ferric-sulfate was introduced upstream of the static mixer, hydrated lime was dosed directly into flocculator tank #1. The clarified water was distributed to Filters 2A, 2B, and 2C. The granular filters were operated in the *downstream controlled gravity* *filtration* mode. Targeted clarifier surface and hydraulic filter loadings were 0.43 gpm/sq.ft. and 6.0 gpm/sq.ft., respectively. HDT in the flocculator cells varied from 17 to 21 minutes.

Influent Total P for this trial averaged 17 μg/L and the lowest filtrate average value was equal to 13.7 μg/L.

TRIAL 7 (days 20 to 27):

In the presence of both a coagulant and a coagulant aid, Total P removal efficiencies of clarification and granular media filtration were investigated. The applied treatment chemicals were alum and A-1849 polyacrylamide. The alum dosage was 10 mg/L. The anionic polymer was dosed at 0.3 mg/L. While alum was introduced upstream of the static mixer, the polymer was applied just downstream of flocculator tank #2. The clarified water was discharged to the filters. The granular filters were operated in the *downstream controlled gravity filtration* mode. Targeted clarifier surface and hydraulic filter loadings were 0.43 gpm/sq.ft. and 6.0 gpm/sq.ft., respectively. HDT in a single flocculator cell varied from 15 to 23 minutes (10 to 12 gpd feed flow rate).

The clarification process reduced the Total P concentration by about 40 percent. Total P was further reduced by all the tested filters. With the exception of the 'Polystyrene' filter column, effluent Total P concentrations of all filters were below 10 μg/L Total P.

TRIAL 8 (days 20 to 27):

The objective of this trial was to test Total P removal efficiency of the clarification process at high hydraulic loading rates. The only treatment chemical was ferric-sulfate added prior to static mixing at a dosage concentration of about 10 mg/L. The performance of the lamella clarifier was tested at 0.71 gpm/sq.ft. Corresponding to this flow rate, individual HDT in three flocculator chambers varied from 10 to 18 minutes (roughly 10 to 20 gpm feed rate).

At the applied testing conditions, the high rate clarification process has shown no Total P removal.

TRIAL 9 (days 28 to 30):

Trial 9 evaluated *direct in-line filtration.* Alum was dosed at a concentration of 10 mg/L prior to static mixing and following coagulation, the chemically treated water was sent to the 'Humics', 'Wahnbach' and 'Shale' filters. The hydraulic filter loading rate was 6.0 gpm/sq.ft. The filters were operated in the *downstream controlled gravity filtration* mode. Only the 'Humics' configuration showed appreciable (approximately 20 percent) Total P removal and the average filtrate concentration from this filter during Trial 9 was equal to 16.8 μg/L.

TRIAL 10 (days 28 to 30):

The two treatment chemicals employed were ferric-sulfate and the anionic polymer, and the coagulant was dosed at a concentration of 10 mg/L with the coagulant aid being applied at 0.3 mg/L. After in-line mixing and 3-stage flocculation, the treated water was introduced to the lamella clarifier. The hydraulic loading of the clarifier was 0.29 gpm/sq.ft. Corresponding to this loading, HDT in each flocculator varied from 25 to 26 minutes. These trials tested the ability of the coagulation, flocculation and clarification processes alone to remove Total P. No Total P was removed during this testing.

TRIAL 11 (days 31 to 34):

Similar to Trial 9, this trial investigated *direct in-line declining rate filtration*. Alum was dosed at a concentration of 10 mg/L prior to static mixing. Following coagulation, the chemically treated water was delivered to the 'LA', 'Swiss' and 'Polystyrene' filters. The applied approach velocity was 4.9 gpm/sq.ft. These tests resulted in no Total P removal from the incoming waters.

TRIAL 12 (days 32 to 35):

This 'clarification only' trial was designed with similar testing conditions as Trial 10. Conditions in this trial included the dosage of 10 mg/L alum and 0.3 mg/L A-1849 polyacrylamide. After coagulation and 3-stage flocculation, the treated water was clarified. HDT in each of the flocculator cells varied from 24 to 25 minutes and a 0.29 gpm/sq.ft. clarifier loading was applied.

In excess of 30 percent Total P was removed by the clarification process. The Total P feed concentration for this test was equal to 25.7 μg/L and the clarified effluent was equal to 17.5 μg/L.

TRIAL 13 (days 31 to 34):

Direct in-line filtration was investigated. The coagulant ferric-sulfate was dosed prior to static mixing. The applied dosage concentration was 10 mg/L. Following coagulation, the chemically pretreated water was distributed to the 'Humics', 'Wahnbach' and 'GE' filters. The applied hydraulic filter loading was 4.9 gpm/sq.ft. The granular media filters were operated in the *declining rate gravity* mode. No Total P was removed from the incoming waters during this test.

TRIAL 14 (days 33 to 35):

Trial 14 investigated the clarification process without filtration. Ferric-sulfate was introduced prior static mixing at a concentration of 10 mg/L. The anionic polymer was dosed at 0.3 mg/L level. A 0.29 gpm/sq.ft. clarifier loading was adjusted and the clarified water was wasted. HDT in an individual flocculator chamber varied from 24 to 25 minutes (equivalent to a feed flow rate of approximately 8 gpm). No Total P was removed during this test.

TRIAL 15 (days 36 to 39):

Total P removal efficiency of different filter media in the absence of both flocculation and chemically assisted sedimentation processes was evaluated. The *direct in-line declining rate gravity filtration* process was identical to the one used in Trial 13, with the exception of the tested filters. The chemically treated water was discharged to the 'LA', 'Swiss' and 'GE' filters. No Total P was removed from the incoming waters during this test.

TRIAL 16 (days 36 to 39):

Trial 16 tested Total P removal efficiency of the clarification process using 10 mg/L alum, and 0.3 mg/L A-1849 polyacrylamide. The clarifier loading and HDT in a flocculator chamber were 0.29 gpm/sq.ft. and 25.5 minutes, respectively. Trial 16 is a duplication of Trial 12 with the exception of clarifier underdrain recycling. While no recycling was used in Trial 12, this test applied solids recycling from the clarifier to flocculator #2 at a rate corresponding to approximately 16 percent of the raw water feed. No Total P was removed form the feed waters during this test.

TRIAL 17 (days 36 to 39):

Trial 17 is a replicate of Trial 11 with the exception of using different filters. *Direct in-line declining rate gravity filtration,* with an alum dosage concentration of 10 mg/L, was used in both of these tests. No polymer was added. The hydraulic filter loading was 4.9 gpm/sq.ft. The chemically treated water was introduced to the 'Humics', 'Wahnbach' and 'Shale' filters. No Total P was removed from the incoming waters during these tests.

TRIAL 18 (days 36 to 39):

Total P removal efficiency by clarification was investigated in Trial 18. Ferric-sulfate and A-1849 polyacrylamide were dosed at 10 mg/L and 0.3 mg/L concentrations, respectively. While the coagulant was injected prior to static mixing, the coagulant aid was applied prior to flocculator #3. Corresponding to the targeted clarifier loading of 0.29 gpm/sq.ft., the HDT in a single flocculator unit varied from 25 to 38 minutes (equivalent to 5 to 8 gpm feed flow rate). Clarifier underdrain solids were recycled at a rate equal to 16 percent of the raw water feed. Under the conditions tested, the clarification process could not remove any Total P.

TRIAL 19 (days 41 to 42):

Direct in-line declining rate gravity filtration was the tested treatment process in Trial 19. Alum was added at a dosage of 10 mg/L. The targeted hydraulic filter loading was 4.9 gpm/sq.ft. The chemically-treated water was filtered by the 'LA', 'Swiss' and 'Polystyrene' media.

The 'LA' filter column reduced the Total P concentration from an average of 19 µg/L in the feed waters to 15.5 µg/L in the filtrate. The removal efficiency was approximately 20 percent.

TRIAL 20 (days 40 to 44):

Trial 20 investigated Total P removal achieved by the clarification process. Alum and A-1849 polyacrylamide treatment chemicals were added at 10 mg/L and 0.3 mg/L concentrations, respectively. The coagulant was injected prior to static mixing. The coagulant aid was added downstream of flocculator tank #2. The targeted clarification surface loading was 0.14 gpm/sq.ft. No Total P was removed from the feed waters during these tests.

TRIAL 21 (days 41 to 42):

Direct in-line declining rate gravity filtration was investigated in Test 21. Ferric-sulfate was added at 10 mg/L concentration prior the static mixer. The pretreated water was introduced to the 'LA', 'Swiss' and 'GE' filters. No Total P was removed from the feed waters during these tests.

TRIAL 22 (days 40 to 44):

Trial 22 tested clarification without filtration. Testing conditions included 10 mg/L targeted-dosage of ferric-sulfate and 0.3 mg/L addition of the anionic polyelectrolite. The 0.14 gpm/sq.ft. clarifier surface loading was aimed. The HDT in a flocculator cell varied from 50 to 51 minutes (equal to an approximate 4 gpm feed flow rate). Residual solids were recycled from the clarifier into flocculator #2 at a rate corresponding to approximately 33 percent of the hydraulic unit loading. Besides recycling, residual solids were also wasted at a rate corresponding to 0.2 to 3.0 percent of the unit throughput. Trial results suggest no Total P removal by this clarification process.

TRIAL 23 (days 45 to 49):

Alum and A-1849 polyacrylamide were used for these tests. The coagulant was dosed at a concentration of 10 mg/L prior to flocculator #1. The anionic coagulant aid was applied at 0.1 mg/L just prior to flocculator #3. The clarified water was introduced to 'LA', 'Swiss' and 'Polystyrene' filters. The clarifier and hydraulic filter loadings were 0.14 gpm/sq.ft. and 4.9 gpm/sq.ft., respectively. The accumulated solids were both wasted and recycled from the clarifier. Wastage rate was adjusted to correspond to approximately 6 percent of the unit throughput. Recycling of clarifier underdrain solids into flocculator #2 occurred at a rate of 30 to 34 percent of the hydraulic unit loading of approximately 4 gpm.

Up to 20 percent Total P could be removed by the 'LA' and 'Swiss' filter configurations. The lowest average filtrate Total P produced was 'LA' filter and equaled 18 μg/L with the average feed Total P concentration equal to 22.6 μg/L.

TRIAL 24 (days 45 to 49):

Ferric-sulfate was dosed at 20 mg/L prior to flocculator #1 and A-1849 polyacrylamide was applied at the 0.1 mg/L level for Trial 24. Treated water was filtered using the 'Humics', 'Wahnbach' and 'Shale' columns. The clarifier surface loading was 0.14 gpm/sq.ft. Approach velocity of the filters was adjusted to 4.9 gpm/sq.ft. Solids from the clarifier bottom discharge were both wasted and recycled. While approximately three percent of the daily throughput was wasted, 30 to 40 percent of the underdrain residuals were recycled back to flocculator #2. No Total P was removed from the feed waters during this test.

3.1.1 Screening Results Recommendations Based Upon TRT Input

On August 20, 1999, the second meeting of the Technical Review Team took place and several conclusions and recommendations were made based upon the completed screening testing. **APPENDIX 3.1** and **APPENDIX 3.2** provide copies of the complete meeting minutes from the TRT meeting. The TRT recommendations included the following:

Reconfiguration of Filter Columns

After completing Trial 24 on September 1, 1999, the filter media in the six columns should be removed and replaced.

- ***Filters 1A and 2A***: 'LA' utilizing 200 cm of anthracite (ES = 1.5; UC = 1.4) on top of a 10 cm gravel support layer.

- ***Filters 1B and 2B***: 'Swiss' utilizing 110 cm of expanded shale (ES = 2 to 3) on top of 30 cm sand (ES = 1.5; UC = 1.4) supported by a 10 cm gravel layer.

- ***Filters 1C and 2C***: 'GE' utilizing 60 cm anthracite (ES = 2.0; UC = 1.4) on top of 80 cm sand (ES = 1.1; UC = 1.4) supported by 10 cm gravel layer.

These filter media recommendations were made by the TRT based upon the relative filter run times observed during the screening tests coupled with the ability of the filters to achieve the 10 μg/L Total P target. Headloss measurements were routinely taken during screening tests at multiple depths from each filter column. Headloss increases with respect to length of filter runs were graphically summarized for all screening filter columns (*see* **APPENDIX 3.3**). An example of a typical headloss curve is shown in **FIGURE 3.6** for Filter 1B, the 'Swiss' media. As shown in **FIGURE 3.6**, the filter was run for a total of approximately 30 hours.

During the screening tests, the 'Swiss' expanded shale media and the 'LA' anthracite displayed the longest filter run times (on the order of 30 hours) compared to maximums of 5 to 15-hour runs for the other media (*i.e.*, 'Polystyrene' and 'Humics'). Both 'Swiss' and 'LA' filters produced filtered effluents containing less than 10 μg/L of Total P. Due to this fact and also the ability of these columns to operate longer without backwash cleaning, these were the ones recommended for further testing. A dual media anthracite and sand filter, given the name of 'Green Everglades' (GE) was also recommended for testing to see if the rapid filtration characteristics displayed by the anthracite material coupled with finer enhanced sand filtration ability could be produce long filter runs and enhanced solids separation.

Reconfiguration of Pretreatment Units

After completing Trial 24 on September 1, 1999, the TRT Team also recommended that the coagulation-flocculation-sedimentation process be reconfigured. Flocculator tank #1 was taken out of service and flocculator cell #2 was converted to an extended flash mix chamber. In summary, for Trials 25 through 28, discussed below, coagulation is accomplished using the static mixer and the reconfigured flash mixer tank. The chemically treated water was introduced into the sole flocculator cell (formerly called flocculator #3). While the coagulant was typically introduced prior to the static mixer unit, the coagulant aid was added to the treated water prior entering to the flocculator cell. The utilization of the clarifier depends on the process design. TRT committee suggestions were intended to determine effects of conducting a series of tests using a single stage (only one of the 200-gallon flocculation tanks). Total flocculation time would be reduced from 30 minutes or more to a range of 15 to 20 minutes. Additional screening tests aimed at simultaneous evaluation of the effectiveness of alum versus ferric-salts and direct filtration tests were also recommended by the TRT for future screening tests as well.

The recommended pilot unit reconfigurations were completed within a one-week period and Trial 25 testing commenced on September 9, 1999. **TABLE 3.1** provides a summary of the test results for screening Trials 25 through 28.

3.1.2 Screening Trials 25 though 28

TRIAL 25 (days 50 to 56):

Trial 25 evaluated *direct filtration*. After dispersion of the applied coagulant in the static and flash mixer units, the coagulated water was introduced to a single flocculation cell. Alum was dosed prior static mixing at concentration of 10 mg/L. The anionic coagulant aid was applied to the water prior its entering the flocculator tank at 0.1 mg/L concentration. In the absence of a clarification process, the pretreated water was introduced directly to the 'LA', 'Swiss' and 'GE' filter columns. The applied hydraulic loading of each of these filters was 4.9 gpm/sq.ft.

Testing results suggest that under the conditions tested, all three filters removed Total P with a removal efficiency of 10 to 35 percent. The lowest average Total P concentration was observed in the 'GE' column and equaled 20.3 µg/L. The average Total P concentration in the feed waters during this test was 30.4 µg/L.

TRIAL 26 (days 50 to 56):

Direct filtration was tested using ferric-sulfate as the coagulant. Ferric-sulfate was dosed prior to static mixing at a concentration of 20 mg/L. The A-1849 polyacrylamide coagulant aid was introduced prior to the flocculation process at a target concentration of 0.1 mg/L. In the absence of a clarification process the pretreated water was introduced directly to the 'LA', 'Swiss' and 'GE' reconfigured filter columns. The target hydraulic filter loading was 4.9 gpm/sq.ft. Testing results indicated that the ferric-salt assisted phase separation process could not remove more than 5 percent of the raw water Total P concentration.

Direct filtration tests using ferric-chloride and alum could not produce filtrate Total P results at or near the 10 µg/L target value.

TRIAL 27 (days 57 to 61):

The treatment train consisted of 1) a static mixer; 2) a flash mixer; 3) a single flocculator tank; 4) a lamella clarifier; and 5) the three granular filter columns. The applied treatment chemicals were alum and A-1849 polyacrylamide. While the coagulant was dosed prior to static mixing at a concentration of 10 mg/L, the coagulant aid was applied at the 0.1 mg/L level prior to the flocculator. The pretreated water was introduced to the 'LA', 'Swiss' and 'GE' filter columns. Hydraulic clarifier and filter loading was 0.43 gpm/sq.ft. and 4.9 gpm/sq.ft., respectively.

Testing results show that while approximately 20 percent of the Total P could be removed by the clarifier, two of the operating filters could remove no Total P. The 'LA' filter removed less than 6 percent Total P. The lowest filtrate Total P concentration obtained during this test was in the 'LA' filtrate at a concentration of 27.2 µg/L.

TRIAL 28 (days 57 to 61):

Instead of alum, Trial 28 used ferric-sulfate coagulant at 20 mg/L dosage level. The treatment train consisted of 1) a static mixer; 2) a flash mixer; 3) a single flocculator tank; 4) a lamella clarifier; and 5) the three tested granular filter columns. While the ferric-sulfate was dosed prior to the static mixer, the anionic coagulant aid was applied at 0.1 mg/L level prior to the flocculator. The treated water was filtered using the 'LA', 'Swiss' and 'GE' columns. Hydraulic clarifier and filter loading was 0.43 gpm/sq.ft. and 4.9 gpm/sq.ft., respectively. Approximately 2 percent of the unit throughput was wasted.

Results from these tests suggest that no Total P could be removed by clarification and only small amounts of Total P could be removed through filtration.

3.1.3 <u>Screening Trials Conclusions and Recommendations</u>

Based upon a review of the screening trial results by the TRT members and the CTSS project team, the following conclusions and recommendations were developed from the screening trials:

1) Conventional water treatment operations (*i.e.*, chemical addition, coagulation, flocculation and filtration processes) produced a filtered effluent containing less than 10 μg/L Total P during screening Trials 3, 5 and 7 on Post-STA feed waters as shown in **TABLE 3.1**. These results were obtained using the coagulant alum at a dose of 10 mg/L to 12 mg/L and with 0.3 mg/L to 0.5 mg/L of A-1849 (Cytec) anionic polymer. The corresponding flocculation volume was equal to a total of 400 gallons (*i.e.*, use of both flocculation tanks with total HDTs ranging from 30 to 40 minutes). Flocculation tank velocity gradients as a function of mixing intensity were empirically determined and the results of this relationship are provided in **FIGURE 3.7**. A velocity gradient of 100 (equivalent to 10 RPM in the first stage flocculation tank) and 40 (5 RPM in the second stage tank) were used during Trials 3, 5 and 7. These successful testing conditions should be the starting point for performing additional optimization tests.

2) Combining the superior filtrate Total P quality results with the filters displaying superior hydraulic performance (*i.e.*, the longest run times without clogging) resulted in the selection of the 'GE' (a dual media anthracite and sand media) and 'Swiss' (expanded shale media) filters for further testing. As a quality assurance measure, duplicate columns were recommended for testing during the optimization phase with the 'Swiss' column being duplicated at the South Test Site and the 'GE' at the North Site.

3) Repeated testing of the direct in-line treatment process did not produce significant reductions in the feed water Total P concentration. Direct in-line filtration was eliminated from further consideration as a treatment option.

4) No significant Total P removal was obtained during trials employing residual solids recirculation. Solids recirculation was eliminated from further consideration as a treatment option.

5) Using the 'Bayesian' design approach previously described in Section 2 of this Report, additional testing during the optimization phase would be conducted using selected combinations of the variables and specific conditions provided in **TABLE 3.2**.

6) Due to some anomalous results obtained during the last 10 days of screening tests (*see* Section 3.2 below), additional direct filtration tests should be conducted during optimization testing.

3.2 OPERATIONAL MODIFICATIONS PLANNED FOR ENHANCING PILOT PLANT PERFORMANCE AND PREPARATIONS FOR OPTIMIZATION AND DEMONSTRATION TESTING

The last 10 days of screening tests, represented as Trials 25 through 28 in **TABLE 3.1**, compared the results of direct filtration and conventional water treatment using iron and aluminum salts as coagulants. Testing results showed little, if any, phosphorus removal and on a number of individual tests, filtrate phosphorus concentrations were higher than the feed phosphorus content for the same testing period.

After a thorough review of the pilot unit design and its operations, it was confirmed that the existing facility was capable of producing representative results but that certain operating procedures would need to be incorporated into future testing to compensate for identified pilot facility design peculiarities. The testing results obtained, particularly during the last 10 days of screening, were thought to be adversely impacted by several conditions including:

- Build-up of solids in the flocculation tanks causing excess solids carry over into effluent samples thus contributing to elevated effluent Total P values;

- Dead space regions in the clarifier resulting in solids accumulation and periodic solids carry over; and,

- Non-continuous operation of the CTSS facility which potentially allowed solids to settle and accumulate in the process basins.

Solids build-up in the pilot unit process unit was confirmed during this September time period when all of the tanks were drained and inspected. As much as one inch of accumulated solids (estimated 4 to 6 percent solids content) were observed in the bottoms of the coagulation, flocculation and clarifier process units. Remedial measures incorporated into future testing included the following:

- All treatment trailer process units (*i.e.*, chemical metering, coagulation, flocculation and clarification) would be run as continuously as possible (*i.e.*, 24 hours per day) during all downstream testing in order to reduce the potential for accumulation of settled solids in the process tanks.

- Between each set of test conditions, all coagulation and floc tanks and clarifiers would be drained and thoroughly flushed out to remove any accumulated solids.

- All new sample collection tubing would be installed.

- The sample intake location for the clarifier would be moved into the discharge end of the effluent collection weir box, the point of highest velocity in this process unit.

During the period of September 27 through October 26, 1999, no CTSS testing was conducted in order to prepare for the optimization and demonstration testing. Activities completed during this time included the construction of additional test facilities that involved moving portions of the South Site CTSS Pilot Unit to the North Site. One of the two treatment trailers and three of the nine filter columns were moved to the North Test Site at this time. Splitting up the equipment between the two locations would enable optimization and demonstration testing to be conducted concurrently on Post-BMP and Post-STA representative feed waters. Also at this time, SFWMD was relocating the pump station that would provide feed water to the North Test Site. Relocation of this pumping facility to the Ocean Canal was required due to STA 1 West construction activities. After the North Site construction was completed, optimization testing commenced at both the North and South ENR Test Sites on October 26, 1999.

3.3 OPTIMIZATION PHASE TESTING RESULTS

Using the 'Bayesian' test design approach, optimization testing was conducted in four unique segments. Results of the testing completed in the initial segments were used to optimize the test conditions of latter segments. **FIGURE 3.8** provides a representative schematic diagram of the pilot facilities for both the North and South Testing Sites, showing test configurations for process units employed during optimization testing. During the optimization tests, coagulation volumes were varied from 20 to 220 gallons per minute (approximately 1.5 to 18-minute retention time at a feed flow rate of 12 gallons per minute) and the hydraulic loading rates to the filters ranged from 4.9 to a high of 9.8 gpm/sq.ft. The flocculation volume was set at a constant volume of 400 gallons and the mixing velocity gradient was equal to 100 G in the first stage flocculator and 40 G in the second stage. Clarifier projected, area loading rates ranged from 0.14 up to a high of 0.43 gpm/sq.ft. Both ferric-chloride and alum were tested and anionic polymers (PAM) A-130 and A–1849 were tested as well in different daily trials.

TABLES 3.2 through 3.9 provide a detailed summary of all daily trials and the corresponding test conditions used for each process unit.

Segment 1 optimization testing was conducted between October 26 through November 7, 1999, at both the North (Post-BMP) and South (Post-STA) Test Sites. **TABLE 3.2** provides the testing conditions used daily at the North Site and also provides the filtrate and clarified effluent Total P results obtained during the daily trials. **TABLE 3.3** provides the South Site data (the same testing conditions were used as for the North Site) and shows the Total P results obtained in the clarifier and filtrate samples. The conditions producing the lowest Total P results during this first segment of testing follow:

	North Site	South Site
Feed Flow Rate, gpm	12	12
Clarifier overflow, gpm/sq.ft.	0.28	0.28
Filtrate rate, gpm/sq.ft.	4.9	4.9
Filter media	‘GE’	‘GE’
Coagulant type	Alum	Alum
Coagulant dose, mg/L as element	20	20
Coagulation volume, gallons	220	220
Polymer dose	0.5	0.3
Total P Feed content, μg/L	141	33
Clarifier Total P content, μg/L	58	6
Filtrate, Total P content, μg/L	13.5	<4
Date of Test	11/6/99	11/5/99

Using the test conditions shown above, the South Test Site produced a clarified effluent of 6 μg/L Total P and a filtered effluent of less than 4 μg/L.

The second segment of optimization tests was conducted from November 8 through November 15, 1999. **TABLE 3.4** and **TABLE 3.5** provide the summaries of daily trial testing conditions and Total P filtrate and clarifier results. The conditions producing the lowest Total P results during this segment 2 testing follow:

	North Site	South Site
Feed Flow Rate, gpm	12	12
Clarifier overflow, gpm/sq.ft.	0.28	0.28
Filtrate rate, gpm/sq.ft.	9.8	9.8
Filter media	'GE'	'Swiss'
Coagulant type	Alum	Alum
Coagulant dose, mg/L as element	20	20
Coagulation volume, gallons	200	200
Polymer dose	0.5	0.5
Total P Feed content, μg/L	115	19
Clarifier Total P content, μg/L	30	6
Filtrate, Total P content, μg/L	13	6
Date of Test	11/8/99	11/5/99

During the second segment of optimization testing, North Site tests were again unable to produce a filtrate or clarified Total P value of less than or equal to 10 μg/L. However, the South Site facility produced a filtered effluent of less than 10 μg/L on three different testing days (November 8, 9 and 11) as shown in **TABLE 3.5**. Both ferric-chloride and alum coagulants produced less than 10 μg/L Total P results at the South Site; however, 40 mg/L of the iron salt was required produce a filtrate concentration of 8 μg/L during the November 8 testing trial.

As part of segment 3 testing, the direct filtration treatment technique was evaluated during approximately half of the trials. **TABLE 3.6** provides testing conditions and Total P results for these direct filtration tests conducted during November 17 and 18, 1999, at the North Site. Direct filtration testing was conducted using both alum and ferric-chloride coagulants and both produced marginal results. The lowest Total P concentration obtained in the filtrate samples was equal to 67 μg/L and this value was obtained on a North Site Total P feed concentration of 169 μg/L.

Direct filtration treatment proved no more effective at the South Site than observed during the North Site testing (**TABLE 3.7**). No Total P was removed during these tests as the feed averaged 18 μg/L and direct filtration effluent was equal to 19 μg/L.

Based upon the marginal Total P reductions of the direct filtration tests conducted at both the North and South Sites during this time period, this treatment technique was eliminated from further consideration and was determined to not be a viable technique for removing Total P in EAA surface waters.

The fourth segment of optimization testing produced Total P clarified and filtrate results of less than or equal to 10 µg/L at both the North and South Test Sites. **TABLE 3.8** and **TABLE 3.9** provide the segment 4 pilot unit testing conditions for each daily trial and also show the corresponding Total P effluent results. The conditions producing the lowest Total P results during this segment four optimization testing follow:

	North Site	South Site
Feed Flow Rate, gpm	12	12
Clarifier overflow, gpm/sq.ft.	0.14	0.14
Filtrate rate, gpm/sq.ft.	4.9	4.9
Filter media	'Swiss'	'GE'
Coagulant type	ferric-salt	ferric-salt
Coagulant dose, mg/L as element	40	40
Coagulation volume, gallons	220	200
Polymer dose	0.5	0.5
Total P Feed content, µg/L	163	18
Clarifier Total P content, µg/L	10	10
Filtrate, Total P content, µg/L	4	5
Date of Test	12/1/99	12/1/99

3.3.1 Conclusions Developed from Optimization Testing and Recommendations for the Demonstration Phase

As discussed above, optimization tests were conducted simultaneously at the North and South Test Sites from October 26 through December 3, 1999. The 138 test results (70 at the North Site and 68 at the South Site) showed varying degrees of Total P reduction. Total P removal of up to 97.5 percent (from 163 to 4 µg/L) was achieved at the North Site. The highest Total P reduction was achieved with the use of 40 mg/L of ferric-chloride and 0.5 mg/L of Cytec anionic A-130 polymer (PAM) and with relatively low hydraulic loadings of both the clarifier and the filter columns (0.14 gpm/sq.ft. and 4.9 gpm/sq.ft., respectively. At the South Test Site, up to 87.9 percent Total P reduction (less than 4 µg/L of Total P in effluent samples) was achieved. Conditions corresponding to these removal results included 0.28 gpm/sq.ft. clarifier and 4.9 gpm/sq.ft. hydraulic loading rates and using 20 mg/L of alum as the chemical coagulant. The 'GE' filter provided marginally higher Total P removal than the 'Swiss' media did during the optimization trials.

During the optimization period, direct filtration tests were also performed at the North and South Test Sites. Direct filtration tests consistently provided high, final effluent Total P results at both Sites and, consequently, no further testing of this treatment technique is proposed.

A relatively narrow range of pilot operating conditions have provided the desired 10 μg/L or less Total P effluent results and, based upon the input from the TRT members, the following conditions were recommended for demonstration testing:

	North Site	South Site
Feed Flow Rate, gpm	12	12
Clarifier overflow, gpm/sq.ft.	0.14	0.28
Filtrate rate, gpm/sq.ft.	4.9	4.9
Filter media	'Swiss'/'GE'	'Swiss'/'GE'
Coagulant type	ferric-salt	Alum
Coagulant dose, mg/L as element	40	20
Coagulation volume, gallons	20	20
Flocculation volume, gallons	400	400
Flocculation Blade Speed, RPM (tank 1/tank 2)	10/5	10/5
Flocculation HDT, minutes	33	33
Coagulation HDT, minutes	1.7	1.7
Polymer dose (A-130), mg/L	0.5	0.5
Clarifier waste rate, gpm	0.6	0.6

Both iron and alum coagulants produced low Total P results and testing of each of the chemicals during demonstration trials was consequently recommended.

3.4 DEMONSTRATION TESTING RESULTS

3.4.1 Total P Testing Results

FIGURE 3.9 provides a schematic diagram of the CTSS pilot facility showing the process unit configuration employed during demonstration phase testing. **TABLE 3.10** and **TABLE 3.11** provide the daily test conditions and Total P clarifier and effluent results for the North Site tests for the 'Swiss' and 'GE' columns, respectively. For the entire demonstration testing period of December 4 through December 23, 1999, all clarifier effluent and filtrate Total P analyses were reported at or below 10 μg/L. The average raw water Total P concentration at the North Site during demonstration testing was equal to 164 μg/L. Total P summary results for the North Testing Site follow:

	Average Total P Value (μg/L) for North Site
Feed Water	164
Clarifer Effluent	7
'Swiss' Filtrate	6
'GE' Filtrate	6

FIGURE 3.10 provides a graphical summary of the Total P results obtained at the North Test Site during demonstration testing and provides a comparison of the raw Total P daily results and the pilot facility clarified effluent and filtered analyses. **FIGURE 3.11** provides an expanded scale detail of the North Test Site results and provides the effluent Total P time series data for the filtered samples and the clarified effluent.

TABLE 3.12 and **TABLE 3.13** provide the daily test conditions and Total P clarifier and effluent results for the South Site tests for the 'Swiss' and 'GE' columns, respectively. For the entire demonstration testing period of December 4 through December 23, 1999, all clarifier effluent and filtrate Total P analyses were reported at or below 10 μg/L. The average raw water Total P concentration at the South Site during demonstration testing was equal to 22 μg/L. Total P summary results for the South Testing Site follow:

	Average Total P Value (μg/L) for South Site
Feed Water	22
Clarifer Effluent	7
'Swiss' Filtrate	6
'GE' Filtrate	6

FIGURE 3.12 provides a graphical summary of the Total P results obtained at the South Test Site during demonstration testing and provides a comparison of the raw Total P daily results and the pilot facility clarified effluent and filtered analyses.

3.4.2 Standard of Comparison Additional Demonstration Phase Testing Results

Standard of Comparison (STSOC) water quality testing was conducted during the CTSS demonstration testing phase in accordance with the requirements specified by PEER/B&C (August 1999). The results of the various additional demonstration testing components are provided below.

3.4.3 Water Quality Testing

TABLE 3.14 and **TABLE 3.15** provide summaries of the various chemical constituents tested during the demonstration trials for both the North (Post-BMP) and the South (Post-STA) Test Sites. Composite samples were collected on raw water, clarified effluent and filtrate samples several times during the December demonstration phase of testing and were submitted to the contract laboratory for metals, nitrogen series, TDS, common cations and anions, and TOC.

- ***Total Alkalinity and pH***

  A significant amount of total alkalinity was removed from the feed waters as a result of the CTSS testing. Average alkalinity was reduced from 129 to 38 mg/L at the North Site and from 220 to 114 mg/L at the South Site. The pH was also reduced from an average of 6.8 to 6.0 at the North Site and from 7.1 to 6.4 at the South Site. Reductions of alkalinity and pH are to be expected with the addition of the acidic alum and ferric-chloride coagulants.

- ***Conductivity and TDS***

  The conductivity and TDS of samples are both measures of the dissolved solids content. Addition of metallic salts to EAA surface will result in increases in these parameters. Due to the ferric-chloride addition at the North Site, the chlorides added will contribute to both higher conductivity and TDS results. The average TDS of the feed waters increased from 308 to 358 mg/L at the North Site, and from an average TDS of 581 to 587 mg/L at the South Site. Due to the alum addition as the South Site, the TDS increased due to the added sulfates contained in the coagulant. Conductivity was measured in the field on both feed and effluent samples during demonstration testing as shown in **TABLE 3.15**. The conductivity of the North Site feed samples averaged 578 micromhos/centimeter and

625 micromhos/centimeter in the pilot unit effluent samples. At the South Site, the conductivity in the feed samples averaged 1091 micromhos/centimeters and equaled 1083 in the CTSS pilot unit effluent samples.

- ***Metals***

The North Site demonstration testing was all conducted using the coagulant ferric-chloride. As shown in **TABLE 3.14**, no significant increases (*e.g.*, less than 20 percent difference) were observed in feed versus effluent average sample results for the following metallic constituents:

Boron	Calcium	Lead
Silica	Molybdenum	Magnesium
Selenium	Aluminum	Cobalt
Mercury	Potassium	Iron
Zinc	Vanadium	

Metals at the North Test Site displaying a 20 percent increase or more in the average results when comparing the feed to the CTSS effluent content included:

Metal	Concentration in Feed (mg/L)	Concentration in Effluent (mg/L)
Copper	0.0021	0.0042
Manganese	0.019	0.166
Nickel	0.0013	0.0056

The South Site demonstration testing was all conducted using the coagulant alum. As shown in **TABLE 3.14**, no significant increases (*e.g.*, less than 20 percent difference) were observed in feed versus effluent average sample results for the following constituents:

Sodium	Boron	Calcium	Lead
Silica	Molybdenum	Magnesium	Potassium
Selenium	Cobalt	Copper	Manganese
Nickel	Mercury	Vanadium	Zinc

Iron was the only metal tested at the South Site that displayed a higher average value in the effluent than observed in the influent samples. The average influent iron concentration was equal to 0.07 mg/L and in the pilot unit effluent, the average iron concentration was 0.12 mg/L.

- ***Sulfate***

There were no significant differences in the average concentrations of sulfate in feed versus CTSS effluent samples for the North Test Site. During demonstration testing, the average feed concentration was equal to 36 mg/L and the treated effluent averaged 39 mg/L.

The use of alum at the South Test Site resulted in an increase in the CTSS effluent average effluent sulfate concentration to 164 mg/L from an average feed water content of 50 mg/L.

- ***Total Organic Carbon and Color***

The majority of the color and total organic carbon (TOC) of the EAA surface waters is attributed to the leaching of organic materials from the muck soils into the water column. Alum and ferric-chloride water treatment coagulants readily react with the organic color molecules and reductions in the TOC and color content of the treated waters would be expected.

The average TOC of the feed water at the North Site was equal to 18 mg/L during demonstration testing. Treating these waters with ferric-chloride reduced the average TOC content to 8 mg/L. Influent color at the North Site averaged 153 APHA units. The color was reduced to an average of 22 APHA units in the treated effluent samples.

- ***Turbidity and Total Suspended Solids***

Turbidity of the North Site influent waters averaged 26 NTUs. The treated and clarified pilot unit effluent averaged 1.7 NTUs. At the South Test Site, the average feed turbidity was equal to 0.76 NTUs and the clarified effluent average was equal to 5.5 NTUs.

The total suspended solids (TSS) content of the feed waters at the North Test Site were reduced by the treatment process from an average 27 mg/L to

0.8 mg/L in the clarified effluent. At the South Site, the average feed TSS was equal to 5 mg/L and the clarified effluent averaged 3.3 mg/L of suspended solids. Reductions in feedwater TSS content would be expected as particulate material contained in the surface waters will generally be removed during the water treatment coagulation and flocculation processes.

- ***Dissolved Oxygen***

During the several months of screening and optimization testing at the South Site, the clarified effluent averaged 6.6 mg/L (number of observations = 79) of DO, and the influent averaged 4.7 mg/L (number of observations = 100). The increase in DO is attributed to the aeration resulting from the mechanical mixing of the coagulant with the feed waters. Since DO levels are artificially increased via mechanical aeration associated with the CTSS process, limited significance can be assigned to the DO readings and the only conclusion that can be made is that the CTSS process increase the DO of the treated surface waters.

- ***Testing of Nitrogen Forms***

Analyses for ammonia, nitrate + nitrite, and total kjeldahl nitrogen (TKN) forms were obtained several times on pilot unit feed and effluent samples during demonstration testing.

For the North Test Site pilot unit, the average TKN influent and effluent value equaled 1.6 mg/L as N (**TABLE 3.14)**. Nitrate + nitrite data was equally comparable as the feed samples averaged 0.54 mg/L as N and the clarified effluent samples averaged 0.53 mg/L. Average ammonia values in the influent were equal to 0.045 mg/L as N and in the clarified effluent from the pilot system, ammonia values were somewhat higher and averaged 0.089 mg/L as N.

South Test Site influent versus effluent data for ammonia, nitrate + nitrite and TKN all recorded virtually identical results.

The CTSS treatment system had no observed effect on the forms of nitrogen tested during the demonstration experiments at both the North and South Test Sites.

3.4.4 SFWMD Low Level Mercury Results

Representatives from SFWMD collected feed and filtrate samples for trace level mercury analysis five times during the December Pilot Study demonstration period. Analyses were performed for filtered/total filtered methyl mercury and filtered and total mercury on representative grab samples of feed and filtrate samples at the North and South Test Sites. Total mercury and methyl mercury analyses were also collected and analyzed on the clarifier underdrain solids.

The average total mercury concentration of the feed samples was equal to 6.176 nanograms/L and 1.352 nanograms/L, while the average total mercury filtrate concentration was 0.306 nanograms/L and 0.500 nanograms/L, at the North and South Sites, respectively. Unfiltered total mercury was reduced approximately 95 percent at the North Site and 63 percent at the South Site. Filtered total mercury was reduced approximately 65 percent at the North Site and 31 percent at the South Site. Unfiltered methyl mercury was reduced approximately 66 percent at the North Site. The unfiltered methyl mercury concentration at the South Site was unchanged as was the filtered methyl mercury concentrations at both the North and South Sites. Mercury removed by CTSS is accumulated in the clarifier underdrain solids as shown in the **TABLE 3.16**. The concentration of total mercury in the concentrated solids from the CTSS treatment system was equal to 81 nanograms/liter at the North Test Site and 7.9 nanograms/liter at the South.

3.4.5 Bioassay and Algal Growth Potential (AGP) Results

Bioassay and AGP analyses were performed by the FDEP Biology Section and Hydrosphere Research on CTSS treatment technology water samples collected during the latter part of optimization and during demonstration of pilot testing (November through December 1999). Summary results for the bioassay and AGP analyses are provided in **TABLE 3.17**.

A total of three bioassay samples were performed on the CTSS feed water and filtrate sample pairs. Feed and filtrate samples were collected simultaneously to determine if any observed effects were the result of the feed waters or from the CTSS treatment process. Of all the testing conducted, there was only a slight to moderate effect on the reproduction rate of the water flea shown in two of the CTSS filtrate samples that was not observed in the feed water sample collected at the same time. On November 29, 1999, the CTSS North Site filtrate sample showed a slightly reduced rate of reproduction for the water flea test organism that was not shown in the feed sample. On this same day, a slight reduced rate of reproduction for the same organism was displayed in the filtrate sample collected at the South Site that was also not shown in the feed sample.

A significant toxicity effect was displayed in both the feed waters and CTSS filtrate samples for the fish, waterflea and algal test organism for samples collected on December 7, 1999. No immediate cause for this significant toxicity on both the feed water and effluent samples could be identified.

There was no significant impact identified from the bioassay sampling completed during testing that could be attributed to the CTSS treatment system.

3.4.6 Residual Solids Characterization and Testing

Clarifier underdrain solids and filter backwash solids were pumped to nearby aboveground storage tanks and lagoons. The solids were allowed to settle to the bottom of the tanks and the supernatant overflowed the top of the tanks and flowed to the lagoons and ultimately was returned to the ENR. Solids were routinely drained from the storage tanks into the lagoons for long term storage to assess settling properties and until they could be chemically characterized. Offsite disposal of solids occurred only after full toxicity analysis was conducted to ensure they contained no hazardous substances. On December 14, 1999, during demonstration testing, representative samples of these underdrain samples were collected and submitted to the FDEP Laboratory in Tallahassee for full toxicity characteristic leachate procedure (TCLP) analyses. The results of the samples collected from both the North and South Testing Sites are provided in **TABLE 3.18**. As shown in **TABLE 3.18**, all of the analytical results on the residual solids from both the North and South Test Sites were well below respective allowed limits for TCLP parameters and, by definition, the CTSS residual solids are non-hazardous.

Based upon these non-hazardous test results, arrangements were made with local EAA farmers for application of the solids onto agricultural land. The results of these land application trials are provided in **APPENDIX 7**.

- ***Underdrain Solids Characterization***

  Clarifier underdrain solids were sampled three times during demonstration tests. **TABLE 3.19** provides the average analytical results for the settled solids at the North (Post-BMP) and South (Post-STA) locations. These samples were collected during the time that solids were being pumped from the bottom of the clarifier process tank. Even though these settled materials are referred to as "solids," the results of the analyses are provided in units of "mg/L" due to their dilute nature. As shown in **TABLE 3.19**, the suspended solids content of these underdrain solids range from 0.1 to 0.2 percent (1,480 to 1,980 mg/L TSS).

  As shown in **TABLE 3.19**, the Total P content of the underdrain solids ranged from a low 0.69 mg/L to 1.99 mg/L, and the TKN concentration varied from 6 mg/L as N to 12 mg/L as N.

- ***Clarifier Underdrain Solids Production Rates***

  Clarifier underdrain solids production rates were calculated for the pilot units using data gathered during the demonstration period. The effective clarifier blowdown rate was 0.6 gallons per minute. Using clarifier loading rates, the blowdown rate and average TSS concentrations, solids production rates ranged from 1145 pounds of dry solids per million gallons of treated water at the ENR effluent location (Post-STA residual solids production rate) to 1720 pounds of dry solids per million gallons treated at the ENR influent (Post-BMP) site.

- ***Residual Solids Dewatering Trials***

  HSA contracted two laboratories to assess the dewatering characteristics of supplied residual solids. These laboratories were:

  1. ASHBROOK Laboratories, and
  2. USFilter, Dewatering Systems Group.

  HSA provided four distinct, five-gallon samples of residual solids samples to both laboratories. The samples were 1) North Test Site – alum solids; 2) North Test Site – ferric-solids; 3) South Test Site – alum solids; and 4) South Test Site – ferric-solids.

ASHBROOK Laboratories assessed the dewatering efficiency of a belt filter press and USFilter evaluated the performance of both a belt filter press and a centrifuge.

ASHBROOK Laboratories conducted four belt filter press tests using the supplied residual solids samples on January 18, 2000. Due to the relatively low solids concentration, the samples were typically gravity settled and decanted before each analysis was performed. The reported solids capture efficiency was 95 percent or higher in each test. Tabular results of these tests are provided below:

Residual Solids Dewatering Characteristics - ASHBROOK Laboratories

Residual Solids / Site	Raw Residual Solids*					Dewatered Residual Solids							
	pH	Temp	Ash	VSS	Feed Solids	Hydraulic Loading	Solids Loading	Cake Solids	Belt Speed	Polymer			
										Type	Dosage Conc	Dosag e Rate	Cost
	(-)	(°F)	(%)	(%)	(%)	(gpm/m)	(lb/hr/m)	(-)	(m/min)	(-)	(lbs./ton)	(gpm)	($/ton)
Alum Solids / North	6.85	75	49.7	50.3	12.6	22.5	1,419	28.5	3.05	Percol 712	1.0	0.57	2.0
Alum Solids / South	7.10	50	49.9	50.1	4.32	42.5	919	29.5	2.15	Percol 727	1.5	1.15	3.0
Ferric-Solids / North	7.30	50	65.7	34.3	1.41	65	459	36.5	1.55	Percol 727	3.0	1.3	6.0
Ferric-Solids / South	7.26	75	57.4	42.6	3.60	37.5	676	29.5	1.85	Percol 712	2.0	0.75	3.0

Notes: * gravity settled and decanted before analysis
30 psi belt tension was applied in all tests

Each of the tests resulted in a minimum of 95 percent solids capture. The reported data suggests that dewatering characteristics of solids (both alum and ferric) produced at the North Test Site are better than those produced at the South Site. The ASHBROOK tests indicate that the CTSS residuals can be dewatered and produce solids cakes in the range of 28 to 37 percent.

USFilter conducted eight tests using the supplied residual solids samples. Dewatering characteristics of each of the four supplied solids sample was assessed by both a belt filter and a centrifuge. USFilter concluded that all the tested solids are the “difficult to dewater.”

Belt filter dewatering tests utilized two distinct polymer dosage ranges, 8 to 12 and 8 to 14 pounds per ton of solids. While the lower polymer dosage range was applied to the two alum solids, the higher dosage values were related to the ferric-solids. The treatment efficiency was evaluated in terms of the estimated cake solids percentage content. In terms of this response parameter, residual solids of alum origin (both sites) showed a marginally higher value (11 to 13 percent) when compared to the ferric-solids (10 to 12 percent).

The dewatering efficiency of the centrifuge was 10 to 12 percent in terms of estimated cake solid content. For that efficiency the dosage of 10 to 14 lbs./ton of solids polymer dosage was required. The applied polymer in all the tests was a Cytec anionic emulsion.

Comparison of the test results suggests that the belt filter loaded with alum solids resulted in the highest cake solid content. Because of the experienced operation problems (sticking of solids to the belt filter), USFilter recommended centrifuge as the preferred dewatering equipment. The centrifuge resulted in less operation problems and offers the additional benefits of (1) continuous operation, (2) relatively high hydraulic loading rates, and (3) minimal maintains requirements.

3.4.7 Total Phosphorus Mass Balance Results

The CTSS pilot facilities were intensively monitored, particularly for phosphorus forms throughout the screening, optimization and demonstration phases of the project. Although data was collected during all phases that could have been used for the calculation of Total P mass balances, the pilot conditions were changed frequently during the screening and optimization phases. It was only during the demonstration phase that the pilot facilities operated with a defined set of conditions for an extended period of time (*i.e.*, 25 days). Accordingly, the demonstration phase was selected to be the appropriate phase for calculation of Total P mass balances.

The average experimental conditions for the two demonstration tests were as follows:

(a) ***Post-BMP***:

- Mass Balance Run Time = 15 days
- Pilot Plant Throughput @ 4 gpm = 86,400 gal.
- Average Influent Total P Concentration = 0.158 mg/L
- Average Clarifier Effluent Total P Concentration = 0.006 mg/L
- Volume of Residual Solids Wasted from Clarifier = 10,800 gal.
- Average Clarifier Residual Solids Total P Concentration = 1.49 mg/L
- Total P In = 0.1138 lbs.
- Total P Out In Effluent = 0.0038 lbs.
- Total P Out In Clarifier Residual Solids = 0.1342 lbs.

Difference In-Out -.0242 lbs.
or –21.3%

(b) ***Post-STA***:

- Demonstration Run Time = 15 days
- Pilot Plant Throughput @ 8 gpm = 172,800 gal.
- Average Influent Total P Concentration = 0.027 mg/L
- Average Clarifier Effluent Total P Concentration = 0.006 mg/L
- Volume of Residual Solids Waste from Clarifier = 10,800 gal.
- Average Clarifier Residual Solids Concentration = 0.57 mg/L
- Total P In = 0.0389 lbs.
- Total P Out In Effluent = 0.0081 lbs.
- Total P Out In Clarifier Residual Solids = 0.0513 lbs.

Difference In-Out -.0205 lbs.
or –52.6%

The differences in the mass balances are outside the generally acceptable range of $\pm$15%. Both the Post-BMP and Post-STA results indicated that more phosphorus was being removed from the system with the clarifier residual solids than could be explained by the difference between the influent and effluent from the system.

A post-mortem review of the project residual-solids sampling procedures shows that the clarifier residuals solids sampling port (located in a dead-end section of the clarifier withdrawal pipe) likely produced samples with higher solids and

Total P concentrations than the solids actually removed from the clarifier by the withdrawal pump. The residual solids withdrawal pump, with a capacity of 30 gpm, removed solids for a 7-second interval every 7 minutes of operation. The residual solids sampling port for each clarifier was sampled three times during the demonstration phase -- a factor that probably also contributed to the non-representative sludge results. The residual solids sampling technique is, by far, the most likely area effecting the goodness of the balance as feed flow rates were measured continuously and calibrated several times, and phosphorus influent and effluent values were obtained daily during demonstration testing.

One of the CTSS pilot trailers is currently being operated at an urban stormwater test site (Wellington) as part of another SFWMD project. The other trailer will be operated at one of the ENR Test Cells for a four-month period. A revised sludge sampling protocol will be employed for these projects which will enable the collection of more representative sludge samples and also will allow comparisons to the CTSS procedures. Potentially, a correction factor can be derived that can be applied to the CTSS demonstration Total P mass balances.

Since the residual solids data used to compute the mass balances was also used to determine residual solids production rates for the full-scale system, the worst case implication of the mass balance results is the over-estimation of residual solids generated. If less solids were, in reality, produced by a full-scale system than estimated here, the area requirements for the full-scale land application management program would be less than estimated. For instance, the area estimated for designated land application for a 200 mgd is 1,326 acres (*see* **TABLE 5.1)**. If less residuals were produced, the land application area would be on the order of 700 to 900 acres.

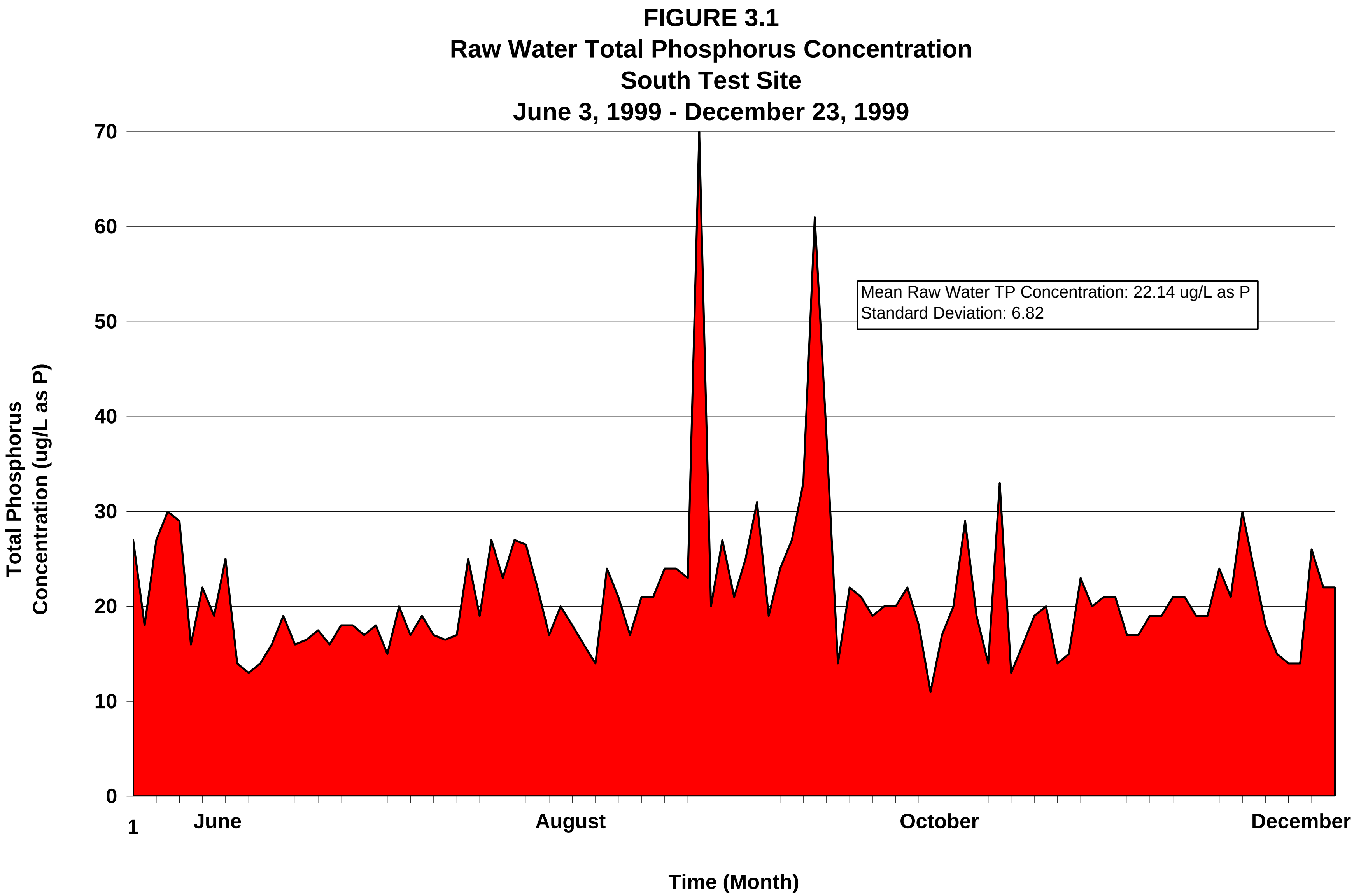
FIGURE 3.1
Raw Water Total Phosphorus Concentration
South Test Site
June 3, 1999 - December 23, 1999
Total Phosphorus Concentration (ug/L as P)
70
60
50
40
30
20
10
0
1
June
August
October
December
Time (Month)
Mean Raw Water TP Concentration: 22.14 ug/L as P
Standard Deviation: 6.82

FIGURE 3.2
Average Monthly Raw Water Phosphorus Data
South Test Site
June 3, 1999 - December 23, 1999

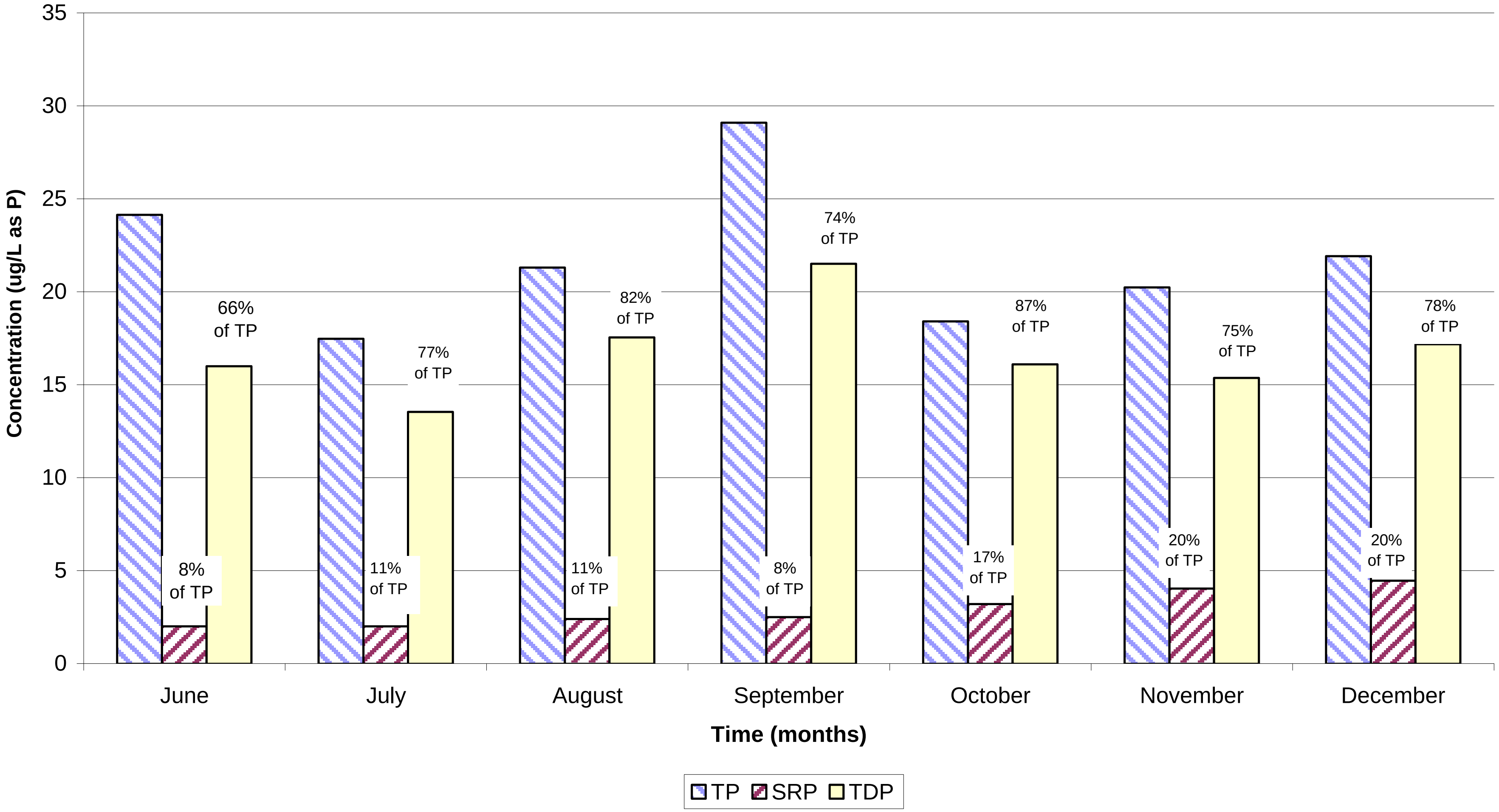

FIGURE 3.3
Raw Water Total Phosphorus (Total P) Concentration
North Test Site
October 26, 1999 - December 23, 1999

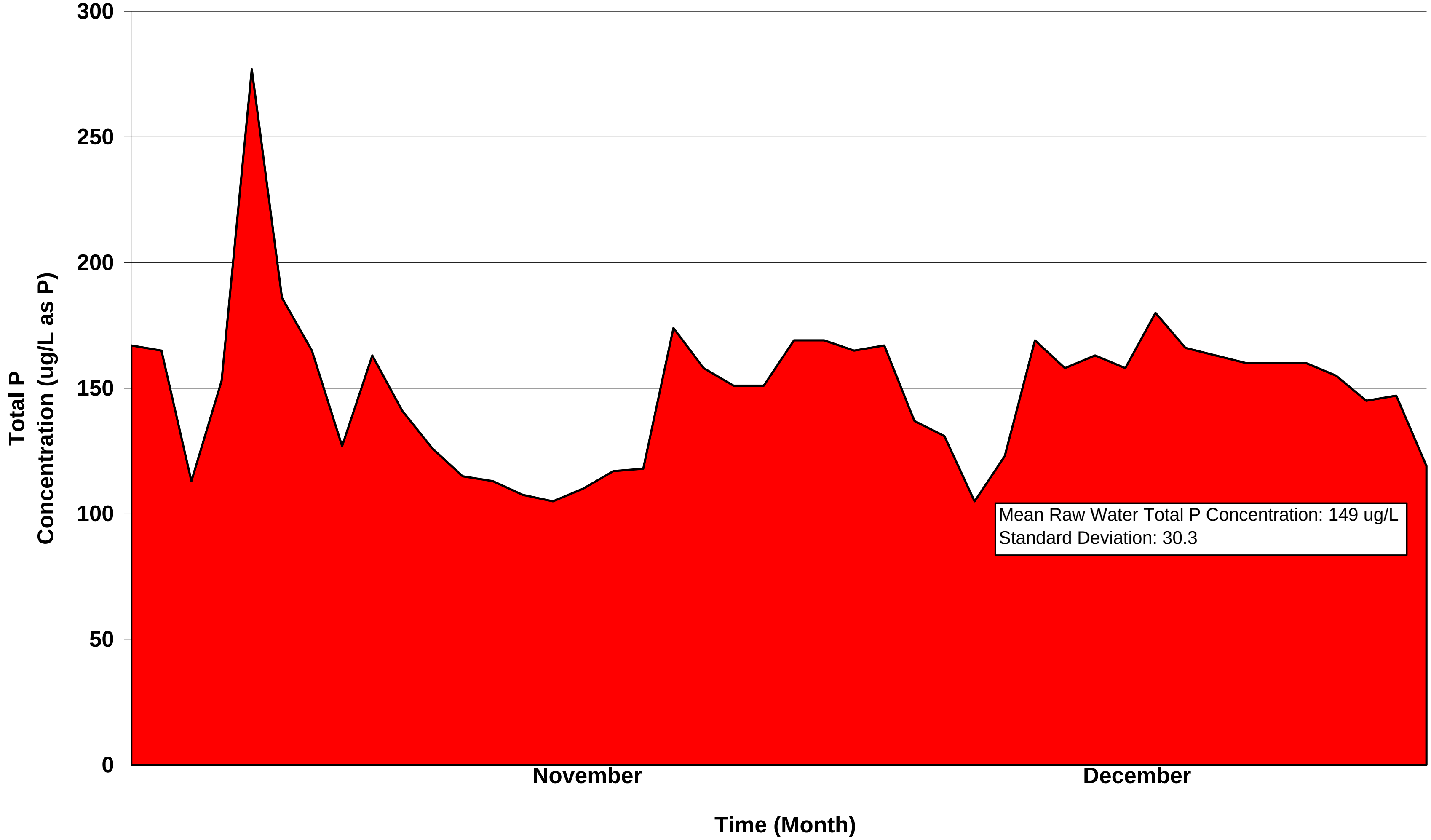

FIGURE 3.4
Average Monthly Raw Water Phosphorus Data
North Test Site
October 26, 1999 - December 23, 1999

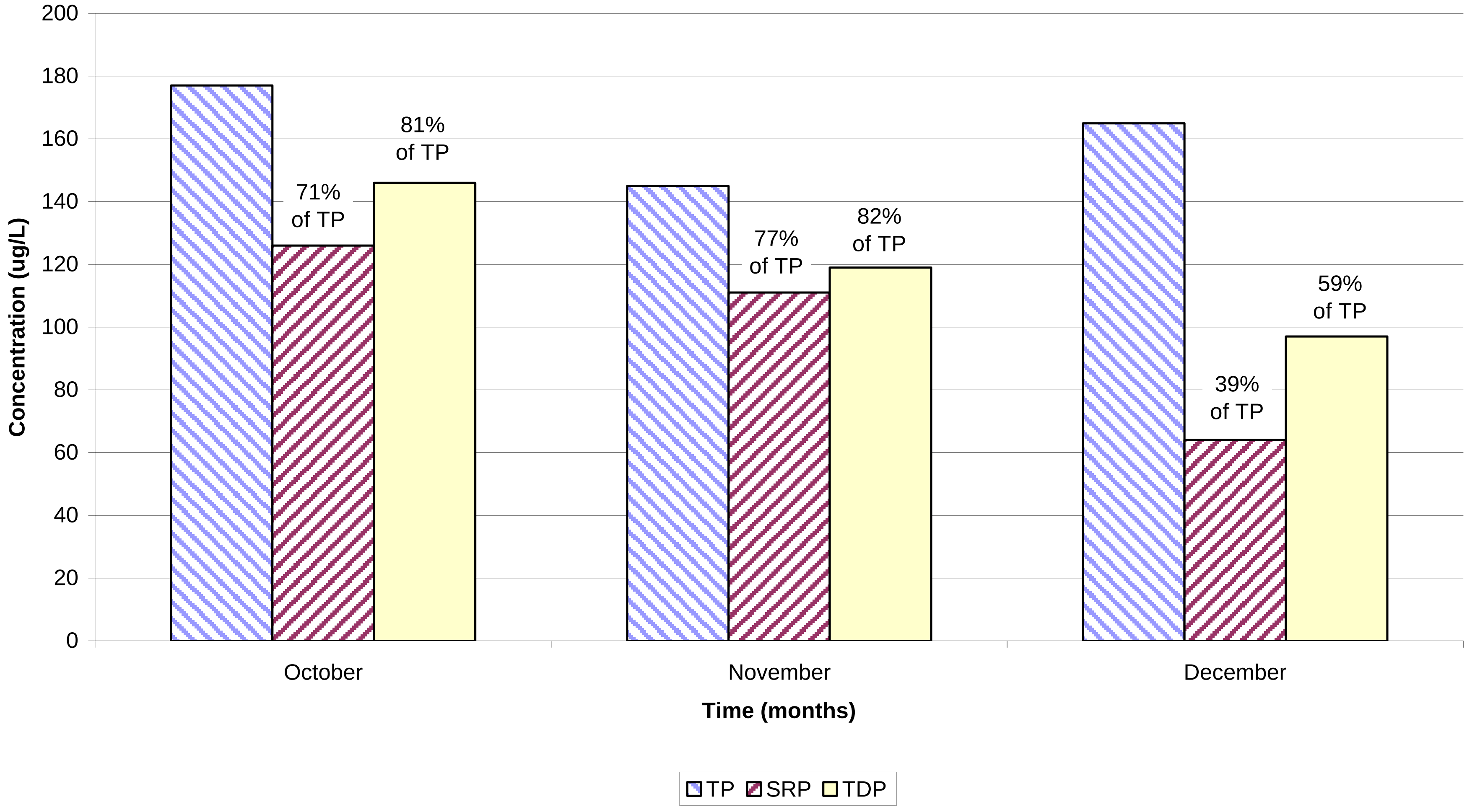

FIGURE 3.5
CTSS Pilot Facility Process During Screening

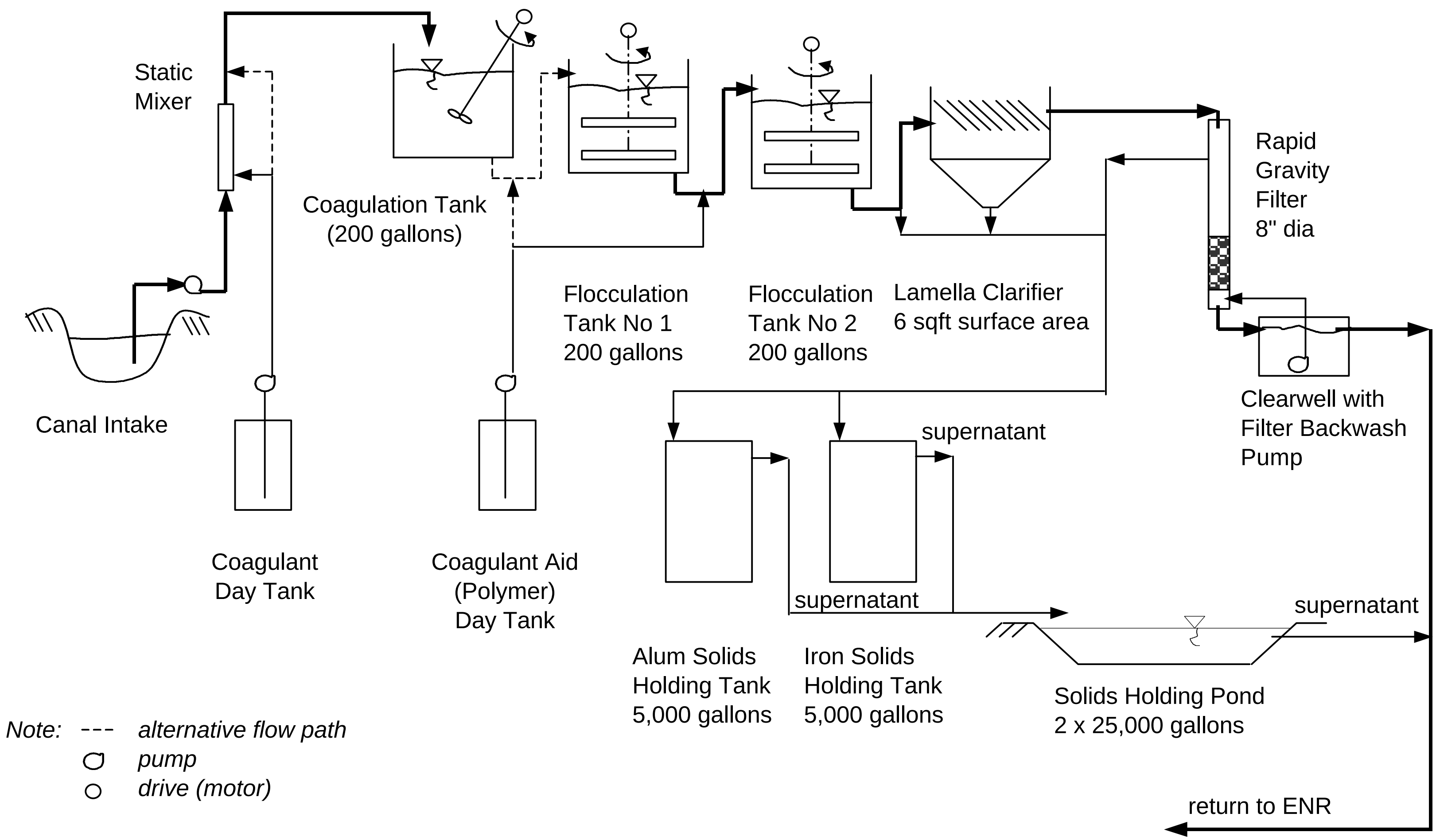

FIGURE 3.6

Headloss - Filter 1B ('Swiss' - dual media)

expanded shale: 102 cm depth, d= 2-3 mm, n = 0.48, Fi = 0.70

sand: 30 cm depth, ES(d_{10}) = 1.5 mm, UC = 1.5, n = 0.38, Fi = 1.00

Days 36, 37, 38, and 39

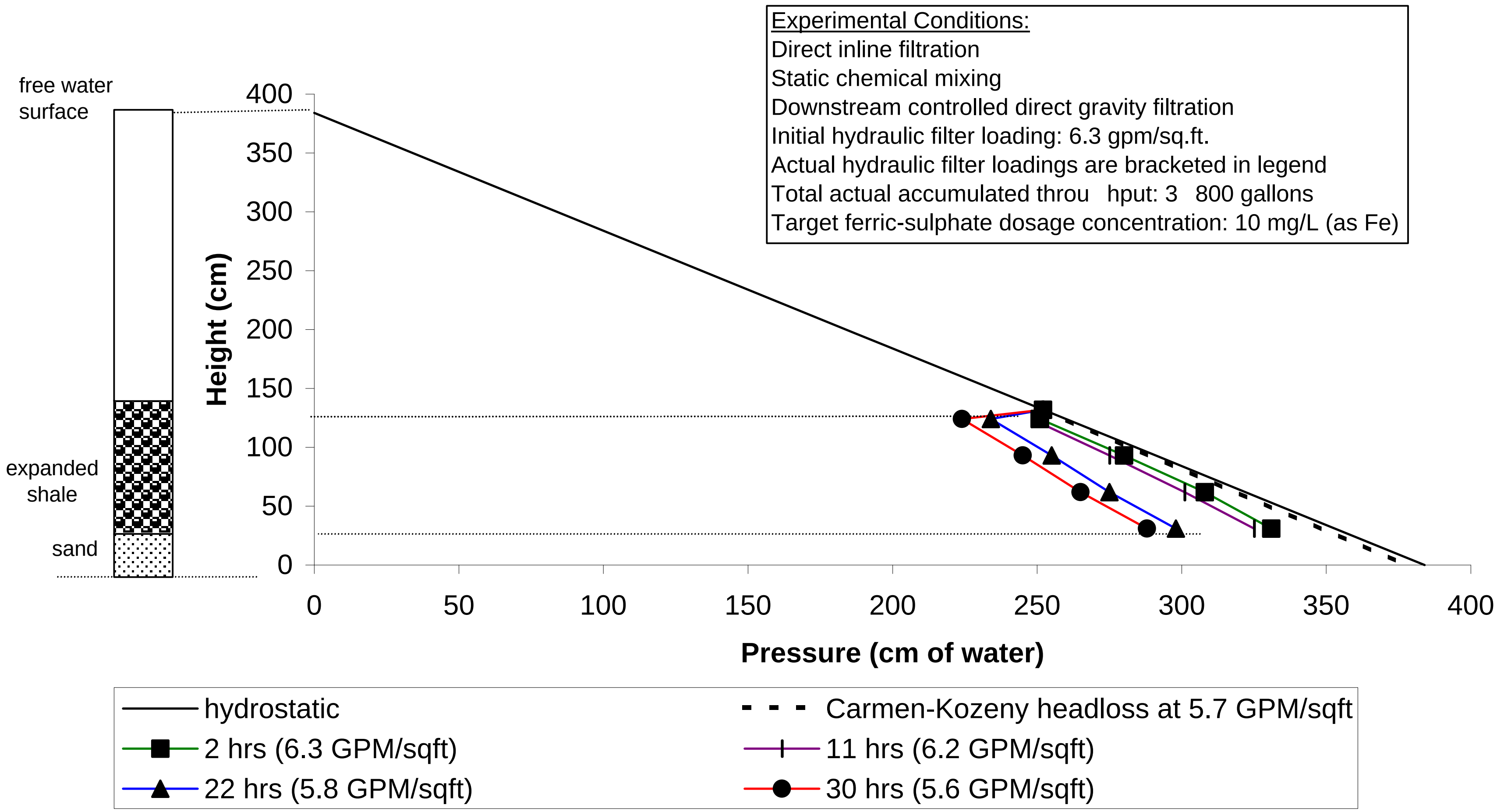

FIGURE 3.7

Velocity Gradient as a Function of

Agitation Intensity and Temperature

for 10 minutes HDT in a 200-gallon usable volume flocculator tank

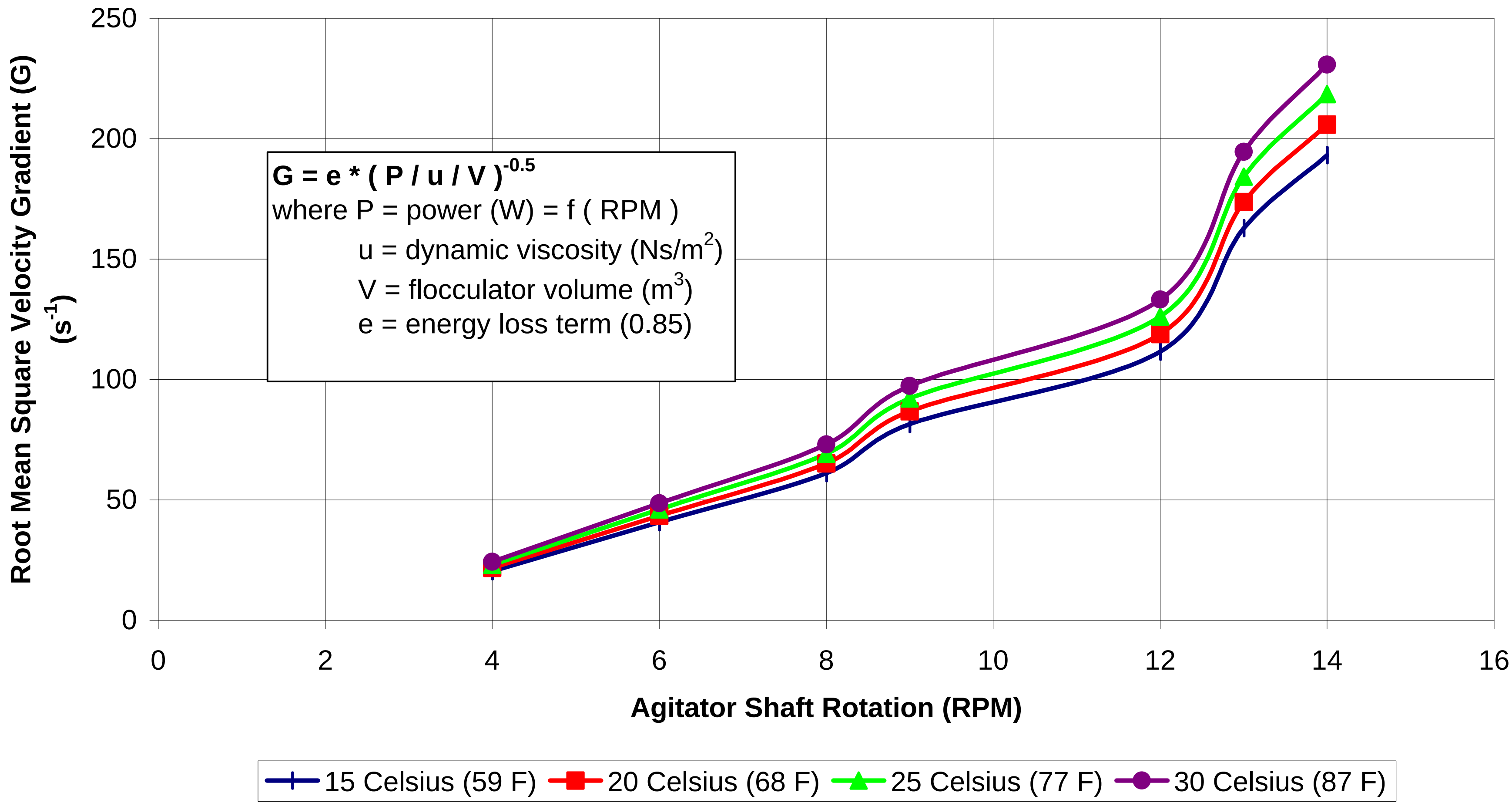

FIGURE 3.8
CTSS Pilot Facility Process During Optimization

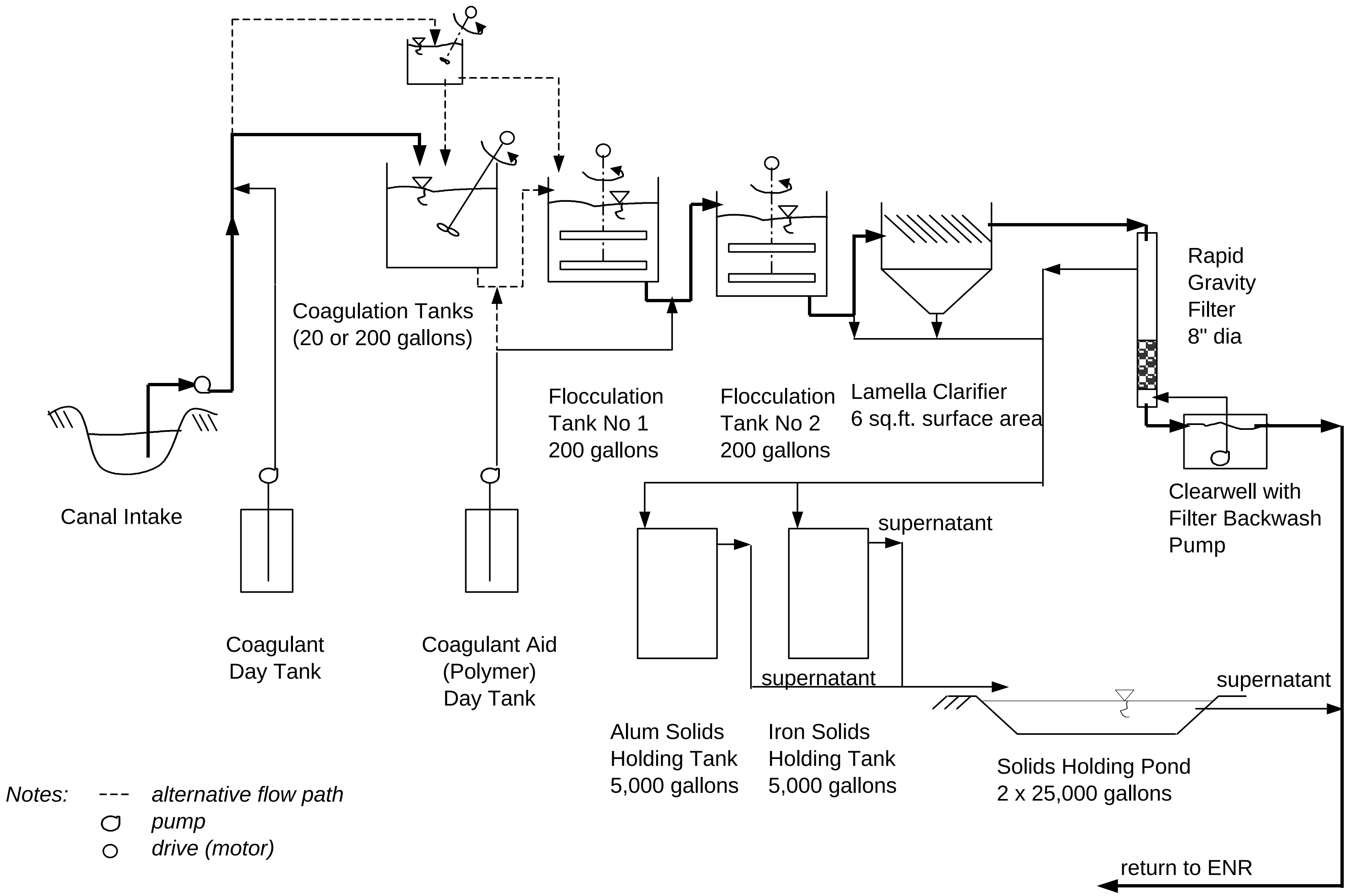

FIGURE 3.9
CTSS Pilot Facility Process During Demonstration

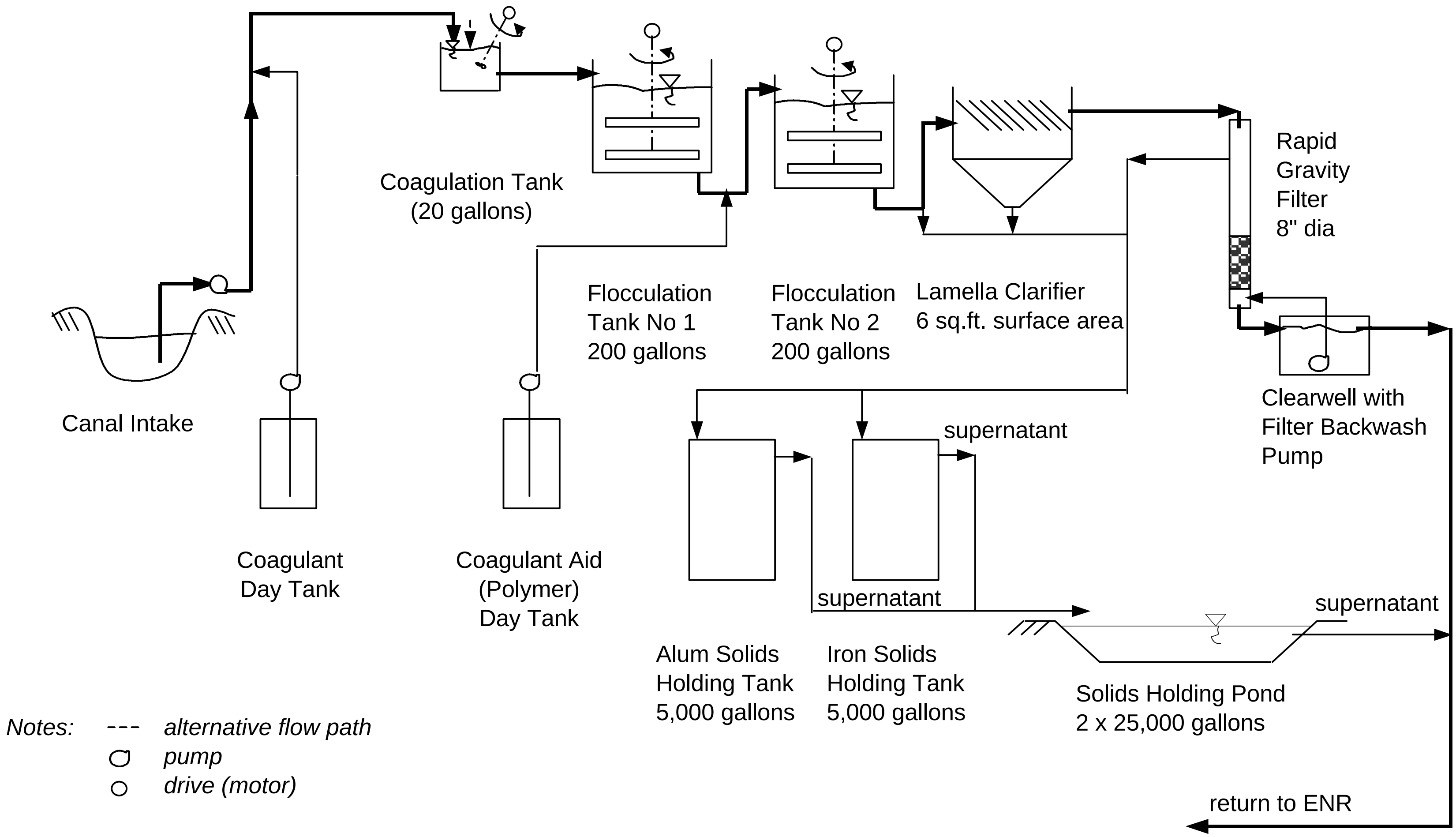

FIGURE 3.10
Concentration of Total Phosphorus (Total P)
in North Test Site Influent (I1)

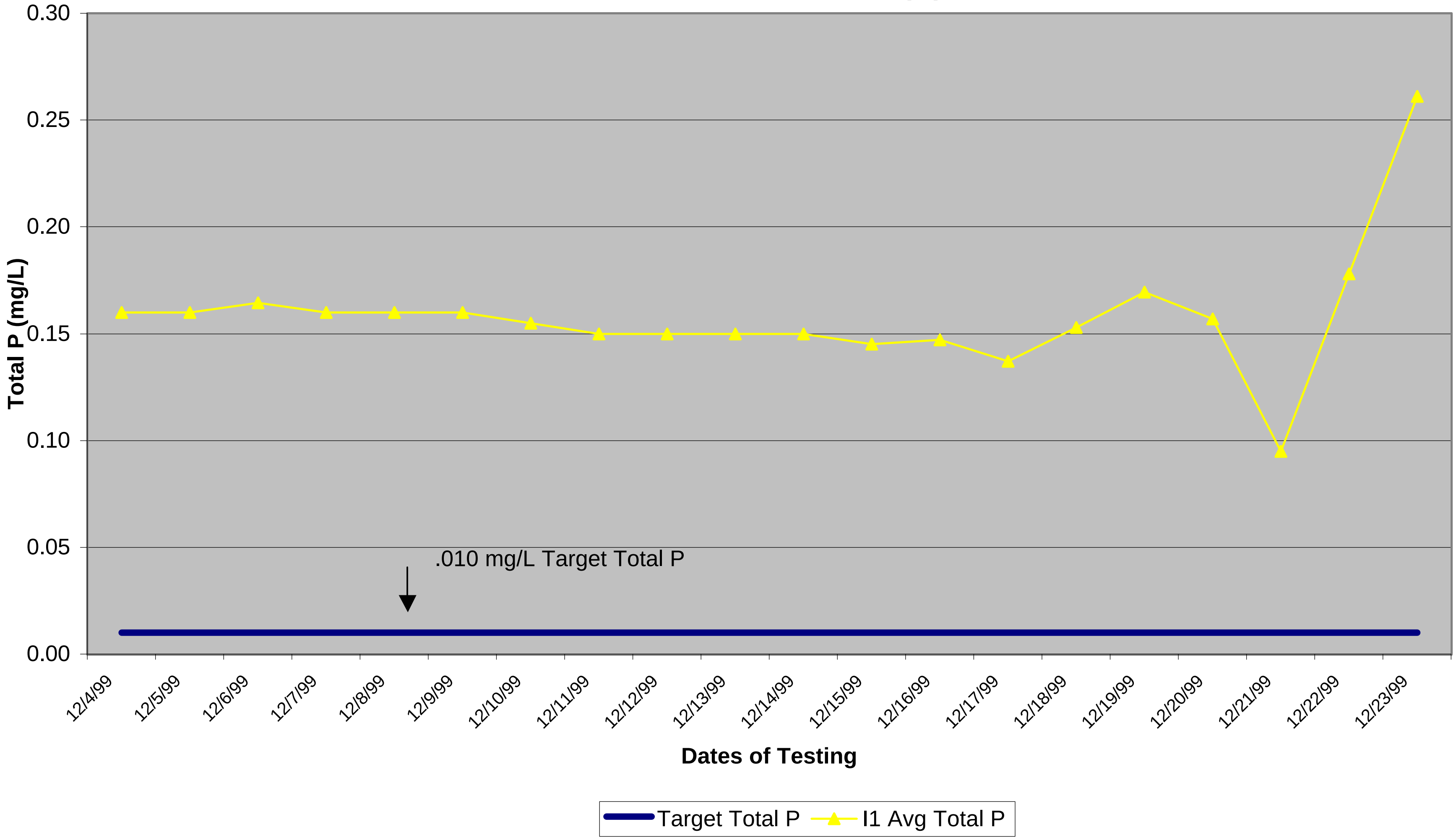

FIGURE 3.11
Expanded Scale Total Phosphorus (Total P) Results of Clarifier Effluent (C1) and Filtrates (F1A and F1B) for the North Test Site

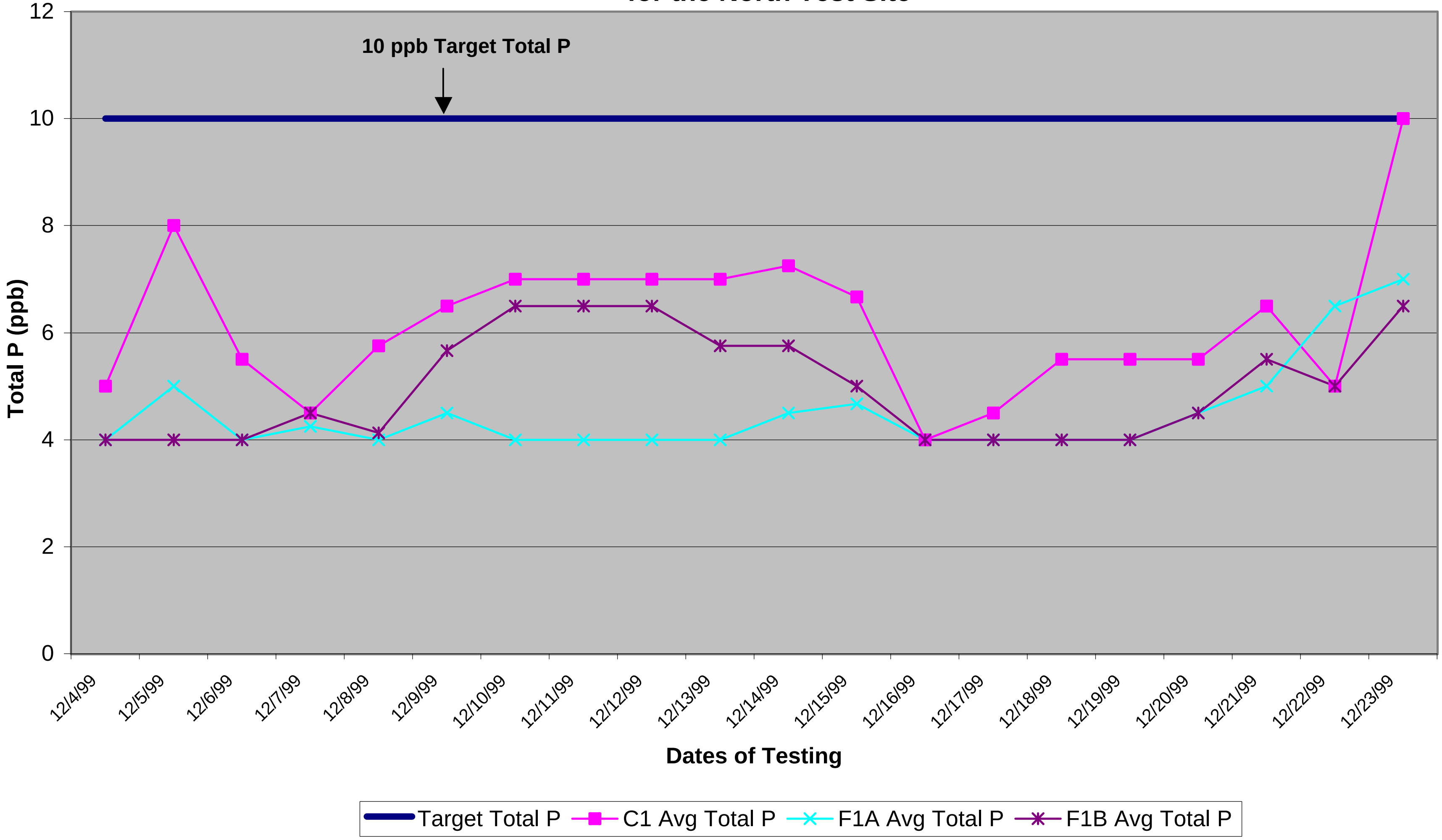

FIGURE 3.12
Total Phosphorus (Total P) Comparison of Influent (I2) vs. Clarifier Effluent (C2) and Filtrates (F2A and F2C) for the South Test Site

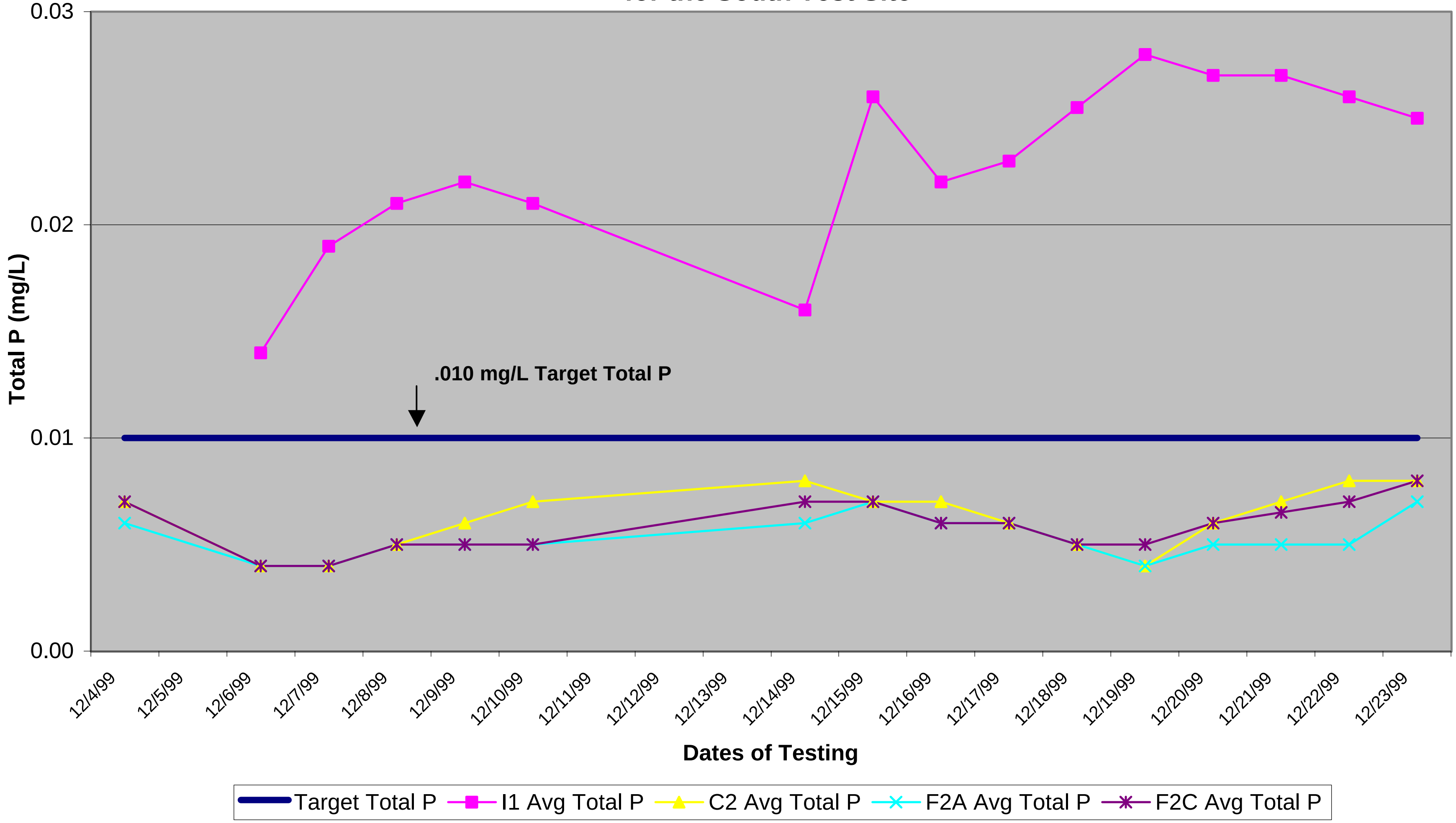

TABLE 3.1
Screening Tests – Variables and System Responses (September 10, 1999)

Test	Days	Operational Variables								Total Phosphorus Concentration (μg/L as P)							
		Treatment Chemicals (mg/L)				Sludge		Hydraulic Loading		Raw Water	Clarifier Effluent	Filtrate***					
		$Al_2(SO_4)_3$	$Fe_2(SO_4)_3$	$Ca(OH)_2$	A-1849	Wasted (%)	Recycled (%)	Clarifier* (gpm/sq.ft.)	Filter gpm/sq.ft.)			1A	1B	1C	2A	2B	2C
1	1 - 6	none	none	none	none	2	none	0.43	4.9	24.5	18.0	19.0	21.3	N/A	20.3	19.8	19.5
2	1 - 6	12	none	none	none	2	none	0.71	-	24.5	25.8	-	-	-	-	-	-
3	7 - 15	12	none	none	0.5	2	none	0.43	4.9	17.7	11.3	N/A	8.2	14.0	-	-	-
4	7 - 15	none	3.5	50	none	2	none	0.43	4.9	17.7	17.2	-	-	-	14.3	12.3	17.5
5	16–19	10	none	none	0.5	2	none	0.43	6.0	17.0	12.0	9.8	8.0	N/A	-	-	-
6	16-19	none	1.5	50	none	2	none	0.43	6.0	17.0	16.0	-	-	-	13.7	13.8	15.5
7	20-27	10	none	none	0.3	2	none	0.43	6.0	17.7	12.3	9.0	9.9	11.3	8.3	9.0	8.7
8	20-27	none	10	none	none	2	none	0.71**	-	17.6	20.3	-	-	-	-	-	-
9	28-30	10	none	none	none	-	-	-	6.0	19.5	-	-	-	-	16.8	19.3	23
10	28-30	none	10	none	0.3	2	none	0.29	-	19.5	26.3	-	-	-	-	-	-
11	31-34	10	none	none	none	-	-	-	4.9	24	-	34.2	36.5	33.3	-	-	-
12	32-35	10	none	none	0.3	2	none	0.29	-	25.7	17.5	-	-	-	-	-	-
13	31-34	none	10	none	none	-	-	-	4.9	24	-	-	-	-	29.8	30	32.5
14	33-35	none	10	none	0.3	2	none	0.29	-	25	34	-	-	-	-	-	-
15	36-39	none	10	none	none	-	-	-	4.9	19.3	-	21.5	22.0	23.5	-	-	-
16	36-39	10	none	none	0.3	2	16	0.29	-	19.3	24	-	-	-	-	-	-
17	36-39	10	none	none	none	-	-	-	4.9	19.3	-	-	-	-	33.5	32.0	32.0
18	36-39	none	10	none	0.3	1	16	0.29	-	19.3	28	-	-	-	-	-	-
19	41-42	10	none	none	none	-	-	-	4.9	19	-	15.5	25.5	24	-	-	-
20	40-44	10	none	none	0.3	2	33	0.14	-	18.4	20.5	-	-	-	-	-	-
21	41-42	none	10	none	none	-	-	-	4.9	19	-	-	-	-	21.8	22.0	23.5
22	40-44	none	10	none	0.3	2	33	0.14	-	18.4	27.2	-	-	-	-	-	-
23	45-49	10	none	none	0.1	2	33	0.14	4.9	22.6	31.0	18.0	21.3	N/A	-	-	-
24	45-49	none	20	none	0.1	2	33	0.14	4.9	22.6	29.6	-	-	-	27.9	N/A	30.0
25	50-56	10	none	none	0.1	-	-	-	4.9	30.4	-	26.7	24.9	20.3	-	-	-
26	51-56	none	20	none	0.1	-	-	-	4.9	23.8	-	-	-	-	22.8	36.3	23.0
27	57-61	10	none	none	0.1	2	none	0.43	4.9	36.6	29.0	27.2	38.8	35.0	-	-	-
28	57-61	none	20	none	0.1	2	none	0.43	4.9	36.6	42.0	-	-	-	42.6	42.6	38.7

Notes:
Tests 1, 3, and 4 suction filtration (constant rate filtration provided by downstream pumping)
Tests 5, 6, 7, 9 downstream controlled gravity filtration (constant rate followed by declining rate filtration provided by gradual opening of effluent valve)
Tests 11, 13, 15, 17, 19, 21, 23, 24, 25, 26, 27, and 28 declining rate gravity filtration (constant valve setting; operation from 1.3Q to 0.6Q, where Q is the target hydraulic loading)

N/A no data available
- not applicable
** based on 28 ft^2 projected lamella area*
*** 12 gpm in days 23 to 26*

Test	Filter					
	1A	1B	1C	2A	2B	2C
1 - 24	'LA'	'Swiss'	polystyrene	'Humics'	'Wahnbach'	shale
25 - 28	'LA'	'Swiss'	'GE'	'LA'	'Swiss'	'GE'

TABLE 3.2
Decoded Design Matrix and System Responses – Optimization Trials
North Test Site - Segment #1 (October 26, 1999 to November 7, 1999)

Date 1999	Exp #	Variable							Total Phosphorus Concentration (µg/L)		
		Filter media	Hydraulic filter loading* (gpm/sq.ft.)	Coagulation Volume (gallons)	Clarifier Surface Loading** (gpm/sq.ft.)	Coagulant Type	Coagulant Dosage Concentration (mg/L)	Polymer (A-130) Dosage Concentration (mg/L)	Raw Water	Clarifier Effluent	Filtrate
October 26	**MN1**	Swiss	4.9	200	0.28	alum	10	0.5	167	98	48.5
(Tuesday)	**MN2**	GE	4.9	200	0.28	alum	10	0.5	167	98	28
October 27	**MN3**	Swiss	9.8	200	0.43	ferric-chloride	40	0.5	165	103	86
(Wednesday)	**MN4**	GE	9.8	200	0.43	ferric-chloride	40	0.5	165	103	68
October 28♦♦♦	**MN5**	Swiss	9.8	20	0.28	ferric-chloride	40	0.3	113	76	68
(Thursday)	**MN6**	GE	9.8	20	0.28	ferric-chloride	40	0.3	113	76	48
October 29	**MN7**	Swiss	9.8	220	0.28	ferric-chloride	40	0.3	153	96	76
(Friday)	**MN8**	GE	9.8	220	0.28	ferric-chloride	40	0.3	153	96	63
November 1	**MN9**	Swiss	9.8	220	0.28	ferric-chloride	20	0.5	277	209	188
(Monday)	**MN10**	GE	9.8	220	0.28	ferric-chloride	20	0.5	277	209	168
November 2	**MN11**	Swiss	9.8	220	0.28	alum	20	0.5	186	93	65.5
(Tuesday)	**MN12**	GE	9.8	220	0.28	alum	20	0.5	186	93	48
November 3	**MN13**	Swiss	9.8	200	0.28	alum	10	0.3	165	146	89
(Wednesday)	**MN14**	GE	9.8	200	0.28	alum	10	0.3	165	146	52
November 4	**MN15**	Swiss	4.9	220	0.28	ferric-chloride	40	0.5	127	55	37
(Thursday)	**MN16**	GE	4.9	220	0.28	ferric-chloride	40	0.5	127	55	30
November 5	**MN17**	Swiss	4.9	200	0.28	alum	20	0.3	163	100	52
(Friday)	**MN18**	GE	4.9	200	0.28	alum	20	0.3	163	100	33
November 6♦♦♦	**MN19**	Swiss	4.9	220	0.28	alum	20	0.5****	141	58	20
(Saturday)	**MN20**	GE	4.9	220	0.28	alum	20	0.5****	141	58	13.5
November 7♦♦♦	**MN21**	Swiss	4.9	220	0.28	ferric-chloride	40	0.5****	126	86	59
(Sunday)	**MN22**	GE	4.9	220	0.28	ferric-chloride	40	0.5****	126	86	46

Notes:

*	*4.9 gpm/sq.ft. ≡ 1.7 gpm hydraulic filter loading*	
**	*projected lamella area*	
***	*20 gallons*	
****	*A-1849 polyacrylamide*	
♦	*lab duplicate*	
♦♦	*filter duplicate*	
♦♦♦	***tests in** addition to 'Bayesian' designed trials*	

Constant flocculation volume is 400 gallons
Even number tests will be conducted in duplicate using the Green Everglades (GE) filter media
Filter 1A: 'GE'; filter 1B: 'Swiss'; filter 1C: 'GE'

TABLE 3.3
Decoded Design Matrix and System Responses – Optimization Trials
South Test Site - Segment #1 (October 26, 1999 to November 7, 1999)

Date 1999	Exp #	Variable							Total Phosphorus Concentration (µg/L)		
		Filter Media	Hydraulic Filter Loading* (gpm/sq.ft.)	Coagulation Volume (gallons)	Clarifier Surface Loading** (gpm/sq.ft.)	Coagulant Type	Coagulant Dosage Concentration (mg/L)	Polymer (A-130) Dosage Concentration (mg/L)	Raw Water	Clarifier Effluent	Filtrate
October 26	**MS1**	Swiss	4.9	200	0.28	alum	10	0.5	22	10	7.5
(Tuesday)	**MS2**	GE	4.9	200	0.28	alum	10	0.5	22	10	7
October 27	**MS3**	Swiss	9.8	200	0.43	ferric-chloride	40	0.5	18	13	8.5
(Wednesday)	**MS4**	GE	9.8	200	0.43	ferric-chloride	40	0.5	18	13	6
October 28♦♦♦	**MS5**	Swiss	9.8	20	0.28	ferric-chloride	40	0.3	11	14	10
(Thursday)	**MS6**	GE	9.8	20	0.28	ferric-chloride	40	0.3	11	14	8
October 29	**MS7**	Swiss	9.8	220	0.28	ferric-chloride	40	0.3	17	20	14
(Friday)	**MS8**	GE	9.8	220	0.28	ferric-chloride	40	0.3	17	20	9
November 1	**MS9**	Swiss	9.8	220	0.28	ferric-chloride	20	0.5	20	18	17
(Monday)	**MS10**	GE	9.8	220	0.28	ferric-chloride	20	0.5	20	18	18
November 2	**MS11**	Swiss	9.8	220	0.28	alum	20	0.5	29	10	6
(Tuesday)	**MS12**	GE	9.8	220	0.28	alum	20	0.5	29	10	8
November 3	**MS13**	Swiss	9.8	200	0.28	alum	10	0.3	19	24	13
(Wednesday)	**MS14**	GE	9.8	200	0.28	alum	10	0.3	19	24	27
November 4	**MS15**	Swiss	4.9	220	0.28	ferric-chloride	40	0.5	14	19	21.5
(Thursday)	**MS16**	GE	4.9	220	0.28	ferric-chloride	40	0.5	14	19	14
November 5	**MS17**	Swiss	4.9	200	0.28	alum	20	0.3	33	6	5.5
(Friday)	**MS18**	GE	4.9	200	0.28	alum	20	0.3	33	6	< 4
November 6♦♦♦	**MS19**	Swiss	4.9	220	0.28	alum	20	0.5****	13	6	6
(Saturday)	**MS20**	GE	4.9	220	0.28	alum	20	0.5****	13	6	5
November 7♦♦♦	**MS21**	Swiss	4.9	220	0.28	ferric-chloride	40	0.5****	16	17	12.5
(Sunday)	**MS22**	GE	4.9	220	0.28	ferric-chloride	40	0.5****	16	17	12

Notes:
- * *4.9 gpm/sq.ft. ≡ 1.7 gpm hydraulic filter loading*
- ** *projected lamella area*
- *** *20 gallons*
- **** *A-1849 polyacrylamide*
- ♦ *lab duplicate*
- ♦♦ *filter duplicate*
- ♦♦♦ ***tests** in addition to 'Bayesian' designed trials*

Constant flocculation volume is 400 gallons
Uneven number tests will be conducted in duplicate using the 'Swiss' filter media
Filter 2A: 'Swiss'; filter 2B: 'Swiss'; filter 2C: 'Green Everglades'

TABLE 3.4
Decoded Design Matrix and System Responses – Optimization Trials
North Test Site - Segment #2 (November 8, 1999 to November 15, 1999)

Date 1999	Exp #	Variable							Total Phosphorus Concentration (μg/L)		
		Filter Media	Hydraulic Filter Loading* (gpm/sq.ft.)	Coagulation Volume (gallons)	Clarifier Surface Loading** (gpm/sq.ft.)	Coagulant Type	Coagulant Dosage Concentration (mg/L)	Polymer (A-130) Dosage Concentration (mg/L)	Raw Water	Clarifier Effluent	Filtrate
November 8 (Monday)	MN23	Swiss	9.8	200	0.28	alum	20	0.5	115	30	17
	MN24	GE	9.8	200	0.28	alum	20	0.5	115	30	13
November 9 (Tuesday)	MN25	Swiss	9.8	200	0.28	alum	10	0.5	113	41	25
	MN26	GE	9.8	200	0.28	alum	10	0.5	113	41	20
November 10 (Wednesday)	MN27	Swiss	9.8	200	0.43	ferric-chloride	20	0.5	107.5	67	43
	MN28	GE	9.8	200	0.43	ferric-chloride	20	0.5	107.5	67	39.5
November 11♦♦♦ (Thursday)	MN29	Swiss	9.8	200	0.43	ferric-chloride	40	0.3	105	49	29
	MN30	GE	9.8	200	0.43	ferric-chloride	40	0.3	105	49	43
November 12 (Friday)	MN31	Swiss	4.9	200	0.43	ferric-chloride	40	0.5	110	34	28
	MN32	GE	4.9	200	0.43	ferric-chloride	40	0.5	110	34	19.5
November 13 (Saturday)	MN33	Swiss	4.9	200	0.28	ferric-chloride	20	0.3	117	92	50
	MN34	GE	4.9	200	0.28	ferric-chloride	20	0.3	117	92	34
November 14 (Sunday)	MN35	Swiss	9.8	220	0.43	alum	20	0.5	118	88	75
	MN36	GE	9.8	220	0.43	alum	20	0.5	118	88	50.5
November 15 (Monday)	MN37	Swiss	4.9	220	0.28	ferric-chloride	40	0.3	174	47	42
	MN38	GE	4.9	220	0.28	ferric-chloride	40	0.3	174	47	34.5

Notes:
- * *4.9 gpm/sq.ft. ≡ 1.7 gpm hydraulic filter loading*
- ** *projected lamella area*
- *** *100 mg/L as Fe*
- ♦ *lab duplicate*
- ♦♦ *filter duplicate*
- ♦♦♦ *tests in addition to 'Bayesian' designed trials*

Constant flocculation volume is 400 gallons; feed flow rate of 12 gpm was maintained
Filter 1A: 'GE'; filter 1B: 'Swiss'; filter 1C: 'GE'

TABLE 3.5
Decoded Design Matrix and System Responses – Optimization Trials
South Test Site - Segment #2 (November 8, 1999 to November 15, 1999)

Date 1999	Exp #	Variable							Total Phosphorus Concentration (µg/L)		
		Filter Media	Hydraulic Filter Loading* (gpm/sq.ft.)	Coagulation Volume (gallons)	Clarifier Surface Loading** (gpm/sq.ft.)	Coagulant Type	Coagulant Dosage Concentration (mg/L)	Polymer (A-130) Dosage Concentration (mg/L)	Raw Water	Clarifier Effluent	Filtrate
November 8	**MS23**	Swiss	9.8	200	0.28	alum	20	0.5	19	6	6
(Monday)	**MS24**	GE	9.8	200	0.28	alum	20	0.5	19	6	13
November 9	**MS25**	Swiss	9.8	200	0.28	alum	10	0.5	20	12	10
(Tuesday)	**MS26**	GE	9.8	200	0.28	alum	10	0.5	20	12	10
November 10	**MS27**	Swiss	9.8	200	0.43	ferric-chloride	20	0.5	14	16	15
(Wednesday)	**MS28**	GE	9.8	200	0.43	ferric-chloride	20	0.5	14	16	14
November 11	**MS29**	Swiss	9.8	200	0.43	ferric-chloride	40	0.3	15	14	9.5
(Thursday)	**MS30**	GE	9.8	200	0.43	ferric-chloride	40	0.3	15	14	8
November 12	**MS31**	Swiss	4.9	200	0.43	ferric-chloride	40	0.5	23	15	14.5
(Friday)	**MS32**	GE	4.9	200	0.43	ferric-chloride	40	0.5	23	15	12
November 13	**MS33**	Swiss	4.9	200	0.28	ferric-chloride	20	0.3	20	21	22
(Saturday)	**MS34**	GE	4.9	200	0.28	ferric-chloride	20	0.3	20	21	20
November 14	**MS35**	Swiss	9.8	220	0.43	alum	20	0.5	21	15	17
(Sunday)	**MS36**	GE	9.8	220	0.43	alum	20	0.5	21	15	13
November 15	**MS37**	Swiss	4.9	220	0.28	ferric-chloride	40	0.3	21	15	17
(Monday)	**MS38**	GE	4.9	220	0.28	ferric-chloride	40	0.3	21	15	12

Notes:
* *4.9 gpm/sq.ft. ≡ 1.7 gpm hydraulic filter loading*
***projected lamella area*
♦ *lab duplicate*
♦♦ *filter duplicate*

Constant flocculation volume: 400 gallons
Uneven number tests will be conducted in duplicate using the 'Swiss' filter media
Filter 2A: 'Swiss'; filter 2B: 'Swiss'; filter 2C: 'Green Everglades'

TABLE 3.6
Decoded Design Matrix and System Responses – Optimization Trials
North Test Site - Segment #3 (November 16, 1999 to November 21, 1999)

Date 1999	Exp #	Variable: Filter Media	Variable: Hydraulic Filter Loading* (gpm/sq.ft.)	Variable: Coagulation Volume (gallons)	Variable: Clarifier Surface Loading** (gpm/sq.ft.)	Variable: Coagulant Type	Variable: Coagulant Dosage Concentration (mg/L)	Variable: Polymer (A-130) Dosage Concentration (mg/L)	Total Phosphorus Concentration (µg/L): Raw Water	Total Phosphorus Concentration (µg/L): Clarifier Effluent	Total Phosphorus Concentration (µg/L): Filtrate
November 16	**MN39**	Swiss	9.8	200	0.43	ferric-chloride	40	0.3	158	N	34
(Tuesday)* **	**MN40**	GE	9.8	200	0.43	ferric-chloride	40	0.3	158	N	44
November 17♦♦♦	**MN41**	Swiss	4.9	220	0	ferric-chloride	20	0.3	151	N/A	129
(a.m.)	**MN42**	GE	4.9	220	0	ferric-chloride	20	0.3	151	N/A	123
November 17♦♦♦	**MN43**	Swiss	4.9	220	0	ferric-chloride	40	0.3	151	N/A	131
(p.m.)	**MN44**	GE	4.9	220	0	ferric-chloride	40	0.3	151	N/A	108
November 18♦♦♦	**MN45**	Swiss	4.9	220	0	alum	10	0.3	169	N/A	134
(a.m.)	**MN46**	GE	4.9	220	0	alum	10	0.3	169	N/A	98
November 18♦♦♦	**MN47**	Swiss	4.9	220	0	alum	20	0.3	169	N/A	89
(p.m.)	**MN48**	GE	4.9	220	0	alum	20	0.3	169	N/A	67
November 19♦♦♦	**MN49**	Swiss	4.9	220	0.14	alum	20	0.5	165	75	44
(Friday)	**MN50**	GE	4.9	220	0.14	alum	20	0.5	165	75	35
November 20♦♦♦	**MN51**	Swiss	4.9	220	0.14	ferric-chloride	40	0.5	167	53	41
(Saturday)	**MN52**	GE	4.9	220	0.14	ferric-chloride	40	0.5	167	53	35
November 21♦♦♦	**MN53**	Swiss	4.9	220	0.14	ferric-chloride	40	0.5	137	84	61
(Sunday)	**MN54**	GE	4.9	220	0.14	ferric-chloride	40	0.5	137	84	44

Notes: *Constant flocculation volume: 400 gallons*
HDT in a single flocculator cell: 49 min 30 sec (Q_{feed} = 4 gpm) unless noted
* *4.9 gpm/sq.ft. ≡ 1.7 gpm hydraulic filter loading*
** *projected lamella area*
*** *HDT in a single flocculator cell: 16 min 30 sec (Q_{feed} = 12 gpm)*
N/A *not applicable*
N *not available*

Even number tests will be conducted in duplicate using the Green Everglades (GE) filter media
Filter 1A: 'GE'; filter 1B: 'Swiss'; filter 1C: 'GE'
♦ *lab duplicate*
♦♦ *filter duplicate*
♦♦♦ ***tests** in addition to 'Bayesian' designed trials*

TABLE 3.7
Decoded Design Matrix and System Responses – Optimization Trials
South Test Site - Segment #3 (November 17, 1999 to November 21, 1999)

Date 1999	Exp #	Variable							Total Phosphorus Concentration (µg/L)		
		Filter Media	Hydraulic Filter Loading* (gpm/sq.ft.)	Coagulation Volume (gallons)	Clarifier Surface Loading** (gpm/sq.ft.)	Coagulant Type	Coagulant Dosage Concentration (mg/L)	Polymer (A-130) Dosage Concentration (mg/L)	Raw Water	Clarifier Effluent	Filtrate
November 16♦♦♦♦											
(Tuesday)											
November 17♦♦♦	MS39	Swiss	4.9	220	0	ferric-chloride	20	0.3	17	N/A	17
(a.m.)	MS40	GE	4.9	220	0	ferric-chloride	20	0.3	17	N/A	16
November 17♦♦♦	MS41	Swiss	4.9	220	0	ferric-chloride	40	0.3	17	N/A	19
(p.m.)	MS42	GE	4.9	220	0	ferric-chloride	40	0.3	17	N/A	19
November 18♦♦♦	MS43	Swiss	4.9	220	0	alum	10	0.3	19	N/A	17
(a.m.)	MS44	GE	4.9	220	0	alum	10	0.3	19	N/A	16
November 18♦♦♦	MS45	Swiss	4.9	220	0	alum	20	0.3	19	N/A	23
(p.m.)	MS46	GE	4.9	220	0	alum	20	0.3	19	N/A	23
November 19♦♦♦	MS47	Swiss	4.9	220	0.14	alum	20	0.5	21	16	13
(Friday)	MS48	GE	4.9	220	0.14	alum	20	0.5	21	16	11
November 20♦♦♦	MS49	Swiss	4.9	220	0.14	ferric-chloride	40	0.5	21	19	18
(Saturday)	MS50	GE	4.9	220	0.14	ferric-chloride	40	0.5	21	19	16
November 21♦♦♦	MS51	Swiss	4.9	220	0.14	ferric-chloride	40	0.5	19	16	17
(Sunday)	MS52	GE	4.9	220	0.14	ferric-chloride	40	0.5	19	16	14

Notes: *Constant flocculation volume is 400 gallons unless noted*
Constant HDT in a single flocculator cell: 49 min 30 sec (Q_{feed} = 4 gpm) unless noted
* *4.9 gpm/sq.ft. ≡ 1.7 gpm hydraulic filter loading*
** *projected lamella area*
N/A not applicable

Uneven number tests will be conducted in duplicate using the 'Swiss' filter media
Filter 2A: 'Swiss'; filter 1B: 'Swiss'; filter 1C: 'Green Everglades'
♦ *lab duplicate*
♦♦ *filter duplicate*
♦♦♦ ***test**s in addition to 'Bayesian' design*
♦♦♦♦ *test was not conducted*

TABLE 3.8
Decoded Design Matrix and System Responses – Optimization Trials
North Test Site - Segment #4 (November 22, 1999 to December 3, 1999)

Date 1999	Exp #	Variable							Total Phosphorus Concentration (µg/L)		
		Filter Media	Hydraulic Filter Loading* (gpm/sq.ft.)	Coagulation Volume (gallons)	Clarifier Surface Loading** (gpm/sq.ft.)	Coagulant Type	Coagulant Dosage Concentration (mg/L)	Polymer (A-130) Dosage Concentration (mg/L)	Raw Water	Clarifier Effluent	Filtrate
November 22	**MN55**	Swiss	4.9	20	0.43	alum	10	0.3	131	41	27
(Monday)	**MN56**	GE	4.9	20	0.43	alum	10	0.3	131	41	23
November 23	**MN57**	Swiss	4.9	20	0.14	alum	20	0.5	105	10	5
(Tuesday)	**MN58**	GE	4.9	20	0.14	alum	20	0.5	105	10	7
November 24	**MN59**	Swiss	4.9	20	0.14	ferric-chloride	20	0.5	123	66	35
(Wednesday)	**MN60**	GE	4.9	20	0.14	ferric-chloride	20	0.5	123	66	28
November 29♦♦♦	**MN61**	Swiss	4.9	220	0.14	alum	10	0.3	169	35	22
(Monday)	**MN62**	GE	4.9	220	0.14	alum	10	0.3	169	35	22
November 30♦♦♦	**MN63**	Swiss	9.8	220	0.14	alum	20	0.3	158	22	12
(Tuesday)	**MN64**	GE	9.8	220	0.14	alum	20	0.3	158	22	16
December 1♦♦♦	**MN65**	Swiss	4.9	220	0.14	ferric-chloride	40	0.5	163	10	4
(Wednesday)	**MN66**	GE	4.9	220	0.14	ferric-chloride	40	0.5	163	10	4
December 2♦♦♦	**MN67**	Swiss	9.8	220	0.14	ferric-chloride	20	0.5	158	42	18
(Thursday)	**MN68**	GE	9.8	220	0.14	ferric-chloride	20	0.5	158	42	24
December 3♦♦♦	**MN69**	Swiss	9.8	220	0.14	ferric-chloride	20	0.3	180	30	19
(Friday)	**MN70**	GE	9.8	220	0.14	ferric-chloride	20	0.3	180	30	14

Notes:
* *4.9 gpm/sq.ft. ≡ 1.7 gpm hydraulic filter loading*
** *projected lamella area*
♦ *lab duplicate*
♦♦ *filter duplicate*
♦♦♦ *tests in addition to 'Bayesian' designed trials*

Constant flocculation volume: 400 gallons
Even number tests will be conducted in duplicate using the Green Everglades (GE) filter media
Filter 1A: 'GE'; filter 1B: 'Swiss'; filter 1C: 'GE'

TABLE 3.9
Decoded Design Matrix and System Responses – Optimization Trials
South Test Site - Segment #4 (November 22, 1999 to December 3, 1999)

Date 1999	Exp #	Variable							Total Phosphorus Concentration (µg/L)		
		Filter Media	Hydraulic Filter Loading* (gpm/sq.ft.)	Coagulation Volume (gallons)	Clarifier Surface Loading** (gpm/sq.ft.)	Coagulant Type	Coagulant Dosage Concentration (mg/L)	Polymer (A-130) Dosage Concentration (mg/L)	Raw Water	Clarifier Effluent	Filtrate
November 22	MS53	Swiss	4.9	20	0.43	alum	10	0.3	19	18	14
(Monday)	MS54	GE	4.9	20	0.43	alum	10	0.3	19	18	14
November 23	MS55	Swiss	4.9	20	0.14	alum	20	0.5	24	15	10
(Tuesday)	MS56	GE	4.9	20	0.14	alum	20	0.5	24	15	10
November 24	MS57	Swiss	4.9	20	0.14	ferric-chloride	20	0.5	21	18	16
(Wednesday)	MS58	GE	4.9	20	0.14	ferric-chloride	20	0.5	21	18	21
November 29♦♦♦	MS59	Swiss	4.9	220	0.14	alum	10	0.3	30	24	19
(Monday)	MS60	GE	4.9	220	0.14	alum	10	0.3	30	24	16
November 30♦♦♦	MS61	Swiss	9.8	220	0.14	alum	20	0.3	24	11	12
(Tuesday)	MS62	GE	9.8	220	0.14	alum	20	0.3	24	11	7
December 1♦♦♦	MS63	Swiss	4.9	220	0.14	ferric-chloride	40	0.5	18	10	8
(Wednesday)	MS64	GE	4.9	220	0.14	ferric-chloride	40	0.5	18	10	5
December 2♦♦♦	MS65	Swiss	9.8	220	0.14	ferric-chloride	20	0.5	15	13	16
(Thursday)	MS66	GE	9.8	220	0.14	ferric-chloride	20	0.5	15	13	13
December 3♦♦♦	MS67	Swiss	9.8	220	0.14	ferric-chloride	20	0.3	14	17	17
(Friday)	MS68	GE	9.8	220	0.14	ferric-chloride	20	0.3	14	17	14

Notes:
- * *4.9 gpm/sq.ft. ≡ 1.7 gpm hydraulic filter loading*
- ** *projected lamella area*
- ♦ *lab duplicate*
- ♦♦ *filter duplicate*
- ♦♦♦ *tests in addition to 'Bayesian' designed trials*

Constant flocculation volume: 400 gallons
Uneven number tests will be conducted in duplicate using the Green Everglades (GE) filter media
Filter 2A: 'Swiss'; filter 2B: 'Swiss'; filter 2C: 'GE'

TABLE 3.10
Coded Design Matrix and System Responses
Demonstration Trials (December 4, 1999 to December 23, 1999)
North Test Site – 'Swiss' Filter

Date 1999	Time	Variable: Hydraulic Filter Loading* (gpm/sq.ft.)	Coagulation Volume (gallons)	Clarifier Surface Loading** (gpm/sq.ft.)	Coagulant Type	Coagulant Dosage Concentration (mg/L as Fe)	Polymer (A-130) Dosage Concentration (mg/L)	Total Phosphorus Concentration (µg/L): Raw Water	Clarifier Effluent	Filtrate
December 4	16:00	4.9	20	0.14	Ferric-chloride	40	0.5	166		< 4
(Saturday)	19:00	4.9	20	0.14	Ferric-chloride	40	0.5	166	5	< 4
December 5	12:30	4.9	20	0.14	Ferric-chloride	40	0.5	166	8	< 4
(Sunday)		4.9	20	0.14	Ferric-chloride	40	0.5	166		
December 6	10:00	4.9	20	0.14	Ferric-chloride	40	0.5	166		
(Monday)	14:00	4.9	20	0.14	Ferric-chloride	40	0.5	163	7	4
	17:00	4.9	20	0.14	Ferric-chloride	40	0.5	163	4	< 4
December 7	13:00	4.9	20	0.14	Ferric-chloride	40	0.5	163	< 4	6
	16:00	4.9	20	0.14	Ferric-chloride	40	0.5	163	5	< 4
(Tuesday)	19:30	4.9	20	0.14	Ferric-chloride	40	0.5		5	< 4
	23:10	4.9	20	0.14	Ferric-chloride	40	0.5		< 4	< 4
December 8	01:00	4.9	20	0.14	Ferric-chloride	40	0.5	160	6	5
(Wednesday)	04:00	4.9	20	0.14	Ferric-chloride	40	0.5	160	5	< 4
	07:30	4.9	20	0.14	Ferric-chloride	40	0.5	160	< 4	< 4
	10:30	4.9	20	0.14	Ferric-chloride	40	0.5	160	5	< 4
	13:30	4.9	20	0.14	Ferric-chloride	40	0.5	160	7	4
	16:30	4.9	20	0.14	Ferric-chloride	40	0.5	160	7	4
	20:00	4.9	20	0.14	Ferric-chloride	40	0.5	160	6	4
	22:30	4.9	20	0.14	Ferric-chloride	40	0.5	160	6	4
December 9	01:00	4.9	20	0.14	Ferric-chloride	40	0.5	160	6	4
(Thursday)	06:30	4.9	20	0.14	Ferric-chloride	40	0.5	160	7	7
	10:00	4.9	20	0.14	Ferric-chloride	40	0.5	160	7	7
	13:30	4.9	20	0.14	Ferric-chloride	40	0.5	160	9	6
	16:00	4.9	20	0.14	Ferric-chloride	40	0.5	160	4	4
	16:30	4.9	20	0.14	Ferric-chloride	40	0.5	160	6	6
December 10	10:00	4.9	20	0.14	Ferric-chloride	40	0.5	155	7	6
(Friday)	13:00	4.9	20	0.14	Ferric-chloride	40	0.5	155	7	7
December 11		4.9	20	0.14	Ferric-chloride	40	0.5	155		
(Saturday)		4.9	20	0.14	Ferric-chloride	40	0.5	155		
December 12		4.9	20	0.14	Ferric-chloride	40	0.5			
(Sunday)		4.9	20	0.14	Ferric-chloride	40	0.5			
December 13		4.9	20	0.14	Ferric-chloride	40	0.5			
(Monday)		4.9	20	0.14	Ferric-chloride	40	0.5			
December 14	9:40	4.9	20	0.14	Ferric-chloride	40	0.5		9	6
(Tuesday)	12:45	4.9	20	0.14	Ferric-chloride	40	0.5	145	4	4
	16:00	4.9	20	0.14	Ferric-chloride	40	0.5	145	6	6
	22:15	4.9	20	0.14	Ferric-chloride	40	0.5	145	10	7
December 15	10:00	4.9	20	0.14	Ferric-chloride	40	0.5	145	9	7
(Wednesday)	13:00	4.9	20	0.14	Ferric-chloride	40	0.5	145	7	4
	15:30	4.9	20	0.14	Ferric-chloride	40	0.5		4	4
December 16	10:00	4.9	20	0.14	Ferric-chloride	40	0.5	147		
(Thursday)	11:00	4.9	20	0.14	Ferric-chloride	40	0.5		4	4
	14:30	4.9	20	0.14	Ferric-chloride	40	0.5		4	< 4
December 17	00:05	4.9	20	0.14	Ferric-chloride	40	0.5		5	< 4
(Friday)	08:45	4.9	20	0.14	Ferric-chloride	40	0.5		< 4	4
	12:00	4.9	20	0.14	Ferric-chloride	40	0.5	119	5	<
	15:00	4.9	20	0.14	Ferric-chloride	40	0.5	155	4	< 4
December 18	11:30	4.9	20	0.14	Ferric-chloride	40	0.5		4	< 4
(Saturday)	14:00	4.9	20	0.14	Ferric-chloride	40	0.5		7	4
December 19	11:30	4.9	20	0.14	Ferric-chloride	40	0.5	152	7	4
(Sunday)	15:30	4.9	20	0.14	Ferric-chloride	40	0.5	187	4	< 4
December 20	11:45	4.9	20	0.14	Ferric-chloride	40	0.5	157	< 4	< 4
(Monday)	15:00	4.9	20	0.14	Ferric-chloride	40	0.5	157	7	5
December 21	8:30	4.9	20	0.14	Ferric-chloride	40	0.5	157	5	4
(Tuesday)	14:00	4.9	20	0.14	Ferric-chloride	40	0.5	157	8	7
December 22	10:45	4.9	20	0.14	Ferric-chloride	40	0.5		5	5
(Wednesday)	15:00	4.9	20	0.14	Ferric-chloride	40	0.5		5	5
December 23	9:00	4.9	20	0.14	Ferric-chloride	40	0.5	261	13	8
(Thursday)	10:45	4.9	20	0.14	Ferric-chloride	40	0.5	261	7	5
AVERAGE								161	6	5

Notes: * *4.9 gpm/sq.ft. ≡ 1.7 gpm hydraulic filter loading*
** *projected lamella area*
♦ *lab duplicate*
♦♦ *filter duplicate*
Constant flocculation volume is 400 gallons

TABLE 3.11
Coded Design Matrix and System Responses
Demonstration Trials (December 4, 1999 to December 23, 1999)
North Test Site – 'GE' Filter

Date 1999	Time	Variable						Total Phosphorus Concentration (µg/L)		
		Hydraulic Filter Loading* (gpm/sq.ft.)	Coagulation Volume (gallons)	Clarifier Surface Loading** (gpm/sq.ft.)	Coagulant Type	Coagulant Dosage Concentration (mg/L as Fe)	Polymer (A-130) Dosage Concentration (mg/L)	Raw Water	Clarifier Effluent	Filtrate
December 4	16:00	4.9	20	0.14	Ferric-chloride	40	0.5	166		< 4
(Saturday)	19:00	4.9	20	0.14	Ferric-chloride	40	0.5	166	5	< 4
December 5	12:30	4.9	20	0.14	Ferric-chloride	40	0.5	166	8	5
(Sunday)		4.9	20	0.14	Ferric-chloride	40	0.5	166		
December 6	10:00	4.9	20	0.14	Ferric-chloride	40	0.5	166		
(Monday)	14:00	4.9	20	0.14	Ferric-chloride	40	0.5	163	7	< 4
	17:00	4.9	20	0.14	Ferric-chloride	40	0.5	163	4	< 4
December 7	13:00	4.9	20	0.14	Ferric-chloride	40	0.5	163	< 4	5
	16:00	4.9	20	0.14	Ferric-chloride	40	0.5	163	5	< 4
(Tuesday)	19:30	4.9	20	0.14	Ferric-chloride	40	0.5		5	< 4
	23:10	4.9	20	0.14	Ferric-chloride	40	0.5		< 4	< 4
December 8	01:00	4.9	20	0.14	Ferric-chloride	40	0.5	160	6	< 4
(Wednesday)	04:00	4.9	20	0.14	Ferric-chloride	40	0.5	160	5	< 4
	07:30	4.9	20	0.14	Ferric-chloride	40	0.5	160	< 4	< 4
	10:30	4.9	20	0.14	Ferric-chloride	40	0.5	160	5	< 4
	13:30	4.9	20	0.14	Ferric-chloride	40	0.5	160	7	4
	16:30	4.9	20	0.14	Ferric-chloride	40	0.5	160	7	4
	20:00	4.9	20	0.14	Ferric-chloride	40	0.5	160	6	< 4
	22:30	4.9	20	0.14	Ferric-chloride	40	0.5	160	6	< 4
December 9	01:00	4.9	20	0.14	Ferric-chloride	40	0.5	160	6	< 4
(Thursday)	06:30	4.9	20	0.14	Ferric-chloride	40	0.5	160	7	4
	10:00	4.9	20	0.14	Ferric-chloride	40	0.5	160	7	< 4
	13:30	4.9	20	0.14	Ferric-chloride	40	0.5	160	9	4
	16:00	4.9	20	0.14	Ferric-chloride	40	0.5	160	4	4
	16:30	4.9	20	0.14	Ferric-chloride	40	0.5	160	6	7
December 10	10:00	4.9	20	0.14	Ferric-chloride	40	0.5	155	7	4
(Friday)	13:00	4.9	20	0.14	Ferric-chloride	40	0.5	155	7	4
December 11		4.9	20	0.14	Ferric-chloride	40	0.5	155		
(Saturday)		4.9	20	0.14	Ferric-chloride	40	0.5	155		
December 12		4.9	20	0.14	Ferric-chloride	40	0.5			
(Sunday)		4.9	20	0.14	Ferric-chloride	40	0.5			
December 13		4.9	20	0.14	Ferric-chloride	40	0.5			
(Monday)		4.9	20	0.14	Ferric-chloride	40	0.5			
December 14	9:40	4.9	20	0.14	Ferric-chloride	40	0.5		9	4
(Tuesday)	12:45	4.9	20	0.14	Ferric-chloride	40	0.5	145	4	< 4
	16:00	4.9	20	0.14	Ferric-chloride	40	0.5	145	6	6
	22:15	4.9	20	0.14	Ferric-chloride	40	0.5	145	10	4
December 15	10:00	4.9	20	0.14	Ferric-chloride	40	0.5	145	9	6
(Wednesday)	13:00	4.9	20	0.14	Ferric-chloride	40	0.5	145	7	< 4
	15:30	4.9	20	0.14	Ferric-chloride	40	0.5		4	4
December 16	10:00	4.9	20	0.14	Ferric-chloride	40	0.5	147		
(Thursday)	11:00	4.9	20	0.14	Ferric-chloride	40	0.5		4	< 4
	14:30	4.9	20	0.14	Ferric-chloride	40	0.5		4	< 4
December 17	00:05	4.9	20	0.14	Ferric-chloride	40	0.5		5	< 4
(Friday)	08:45	4.9	20	0.14	Ferric-chloride	40	0.5		< 4	4
	12:00	4.9	20	0.14	Ferric-chloride	40	0.5	119	5	4
	15:00	4.9	20	0.14	Ferric-chloride	40	0.5	155	4	< 4
December 18	11:30	4.9	20	0.14	Ferric-chloride	40	0.5		4	<4
(Saturday)	14:00	4.9	20	0.14	Ferric-chloride	40	0.5		7	4
December 19	11:30	4.9	20	0.14	Ferric-chloride	40	0.5	152	7	< 4
(Sunday)	15:30	4.9	20	0.14	Ferric-chloride	40	0.5	187	4	< 4
December 20	11:45	4.9	20	0.14	Ferric-chloride	40	0.5	157	< 4	< 4
(Monday)	15:00	4.9	20	0.14	Ferric-chloride	40	0.5	157	7	5
December 21	8:30	4.9	20	0.14	Ferric-chloride	40	0.5	157	5	5
(Tuesday)	14:00	4.9	20	0.14	Ferric-chloride	40	0.5	157	8	5
December 22	10:45	4.9	20	0.14	Ferric-chloride	40	0.5		5	8
(Wednesday)	15:00	4.9	20	0.14	Ferric-chloride	40	0.5		5	5
December 23	9:00	4.9	20	0.14	Ferric-chloride	40	0.5	261	13	7
(Thursday)	10:45	4.9	20	0.14	Ferric-chloride	40	0.5	261	7	7
AVERAGE								161	6	4

Notes:
- * *4.9 gpm/sq.ft. ≡ 1.7 gpm hydraulic filter loading*
- ** *projected lamella area*
- ♦ *lab duplicate*
- ♦♦ *filter duplicate*

Constant flocculation volume is 400 gallons

TABLE 3.12
Coded Design Matrix and System Responses
Demonstration Trials (December 4, 1999 to December 23, 1999)
South Test Site – 'Swiss' Filter

Date 1999	Time	Variable: Hydraulic Filter Loading* (gpm/sq.ft.)	Coagulation Volume (gallons)	Clarifier Surface Loading** (gpm/sq.ft.)	Coagulant Type	Coagulant Dosage Concentration (mg/L as Al)	Polymer (A-130) Dosage Concentration (mg/L)	Total Phosphorus Concentration (µg/L): Raw Water	Clarifier Effluent	Filtrate
December 4	16:15	9.8	20	0.28	alum	20	0.5	14	8	6
(Saturday)	18:00	9.8	20	0.28	alum	20	0.5	14	6	6
December 5		9.8	20	0.28	alum	20	0.5	14		
(Sunday)		9.8	20	0.28	alum	20	0.5	14		
December 6	10:00	9.8	20	0.28	alum	20	0.5	14		
(Monday)	15:00	9.8	20	0.28	alum	20	0.5	19	4	< 4
	18:00	9.8	20	0.28	alum	20	0.5	19	4	4
December 7	09:30	9.8	20	0.28	alum	20	0.5	19	4	4
(Tuesday)	12:30	9.8	20	0.28	alum	20	0.5	21	< 4	4
	15:30	9.8	20	0.28	alum	20	0.5	21	< 4	< 4
	18:45	9.8	20	0.28	alum	20	0.5	21	< 4	< 4
	21:30	9.8	20	0.28	alum	20	0.5	21	< 4	< 4
December 8	00:30	9.8	20	0.28	alum	20	0.5	21	5	< 4
(Wednesday)	03:30	9.8	20	0.28	alum	20	0.5	21	< 4	< 4
	07:00	9.8	20	0.28	alum	20	0.5	21	< 4	< 4
	10:30	9.8	20	0.28	alum	20	0.5	21	< 4	< 4
	13:30	9.8	20	0.28	alum	20	0.5	21	6	5♦♦
	16:00	9.8	20	0.28	alum	20	0.5	22	6	4
	19:20	9.8	20	0.28	alum	20	0.5	22	6	6
	22:00	9.8	20	0.28	alum	20	0.5	22	7	6
December 9	04:00	9.8	20	0.28	alum	20	0.5	22	6	6
(Thursday)	07:00	9.8	20	0.28	alum	20	0.5	22	6	6
	10:30	9.8	20	0.28	alum	20	0.5	22	7	4
	16:30	9.8	20	0.28	alum	20	0.5	21	4	< 4
December 10	12:00	9.8	20	0.28	alum	20	0.5	21	7	
(Friday)	13:00	9.8	20	0.28	alum	20	0.5	21	6	4
	16:00	9.8	20	0.28	alum	20	0.5	16	7	6
December 11		9.8	20	0.28	alum	20	0.5	16		
(Saturday)		9.8	20	0.28	alum	20	0.5	16		
December 12		9.8	20	0.28	alum	20	0.5	16		
(Sunday)		9.8	20	0.28	alum	20	0.5			
December 13		9.8	20	0.28	alum	20	0.5			
(Monday)		9.8	20	0.28	alum	20	0.5			
December 14	10:15	9.8	20	0.28	alum	20	0.5		7	4
(Tuesday)	15:10	9.8	20	0.28	alum	20	0.5		7	6
	21:00	9.8	20	0.28	alum	20	0.5		9	9
December 15	12:00	9.8	20	0.28	alum	20	0.5	26	7	7
(Wednesday)	15:00	9.8	20	0.28	alum	20	0.5	26	7	7
	16:30	9.8	20	0.28	alum	20	0.5	26	6	6
December 16	10:00	9.8	20	0.28	alum	20	0.5	22		
	12:10	9.8	20	0.28	alum	20	0.5	22	7	7
(Thursday)	15:10	9.8	20	0.28	alum	20	0.5	22	7	6
	17:45	9.8	20	0.28	alum	20	0.5	22	7	5
December 17	00:45	9.8	20	0.28	alum	20	0.5	22	7	7
(Friday)	09:50	9.8	20	0.28	alum	20	0.5		5	5
	10:00	9.8	20	0.28	alum	20	0.5	22		
	12:00	9.8	20	0.28	alum	20	0.5		8	8
	14:00	9.8	20	0.28	alum	20	0.5	24	5	5
December 18	13:00	9.8	20	0.28	alum	20	0.5		5	5
(Saturday)		9.8	20	0.28	alum	20	0.5		5	
December 19	12:30	9.8	20	0.28	alum	20	0.5	28	4	5
(Sunday)	15:00	9.8	20	0.28	alum	20	0.5		4	5
December 20	10:30	9.8	20	0.28	alum	20	0.5		4	5
(Monday)	15:00	9.8	20	0.28	alum	20	0.5		4	4
December 21		9.8	20	0.28	alum	20	0.5			
(Tuesday)		9.8	20	0.28	alum	20	0.5			
December 22	13:30	9.8	20	0.28	alum	20	0.5		8	5
(Wednesday)	16:30	9.8	20	0.28	alum	20	0.5	25	8	4
December 23	8:50	9.8	20	0.28	alum	20	0.5	25	5	7
(Thursday)	12:00	9.8	20	0.28	alum	20	0.5		10	7
AVERAGE								26	6	5

Notes:
* *9.8 gpm/sq.ft. ≡ 3.4 gpm hydraulic filter loading*
** *projected lamella area*
♦ *lab duplicate*
♦♦ *filter duplicate*
Constant flocculation volume is 400 gallons

TABLE 3.13
Coded Design Matrix and System Responses
Demonstration Trials (December 4, 1999 to December 23, 1999)
South Test Site – 'GE' Filter

Date	Time	Variable						Total Phosphorus Concentration (μg/L)		
1999		Hydraulic Filter Loading* (gpm/sq.ft.)	Coagulation Volume (gallons)	Clarifier Surface Loading** (gpm/sq.ft.)	Coagulant Type	Coagulant Dosage Concentration (mg/L as Al)	Polymer (A-130) Dosage Concentration (mg/L)	Raw Water	Clarifier Effluent	Filtrate
December 4	16:15	9.8	20	0.28	alum	20	0.5	14	8	8
(Saturday)	18:00	9.8	20	0.28	alum	20	0.5	14	6	5
December 5		9.8	20	0.28	alum	20	0.5	14		
(Sunday)		9.8	20	0.28	alum	20	0.5	14		
December 6	10:00	9.8	20	0.28	alum	20	0.5	14		
(Monday)	15:00	9.8	20	0.28	alum	20	0.5	19	4	4
	18:00	9.8	20	0.28	alum	20	0.5	19	4	< 4
December 7	09:30	9.8	20	0.28	alum	20	0.5	19	4	< 4
(Tuesday)	12:30	9.8	20	0.28	alum	20	0.5	21	< 4	< 4
	15:30	9.8	20	0.28	alum	20	0.5	21	< 4	< 4
	18:45	9.8	20	0.28	alum	20	0.5	21	< 4	< 4
	21:30	9.8	20	0.28	alum	20	0.5	21	< 4	< 4
December 8	00:30	9.8	20	0.28	alum	20	0.5	21	5	< 4
(Wednesday)	03:30	9.8	20	0.28	alum	20	0.5	21	< 4	< 4
	07:00	9.8	20	0.28	alum	20	0.5	21	< 4	< 4
	10:30	9.8	20	0.28	alum	20	0.5	21	< 4	9
	13:30	9.8	20	0.28	alum	20	0.5	21	6	< 4
	16:00	9.8	20	0.28	alum	20	0.5	22	6	6
	19:20	9.8	20	0.28	alum	20	0.5	22	6	6
	22:00	9.8	20	0.28	alum	20	0.5	22	7	7
December 9	04:00	9.8	20	0.28	alum	20	0.5	22	6	
(Thursday)	07:00	9.8	20	0.28	alum	20	0.5	22	6	
	10:30	9.8	20	0.28	alum	20	0.5	22	7	
	16:30	9.8	20	0.28	alum	20	0.5	21	4	
December 10	12:00	9.8	20	0.28	alum	20	0.5	21	7	6
(Friday)	13:00	9.8	20	0.28	alum	20	0.5	21	6	4
	16:00	9.8	20	0.28	alum	20	0.5	16	7	6
December 11		9.8	20	0.28	alum	20	0.5	16		
(Saturday)		9.8	20	0.28	alum	20	0.5	16		
December 12		9.8	20	0.28	alum	20	0.5	16		
(Sunday)		9.8	20	0.28	alum	20	0.5			
December 13		9.8	20	0.28	alum	20	0.5			
(Monday)		9.8	20	0.28	alum	20	0.5			
December 14	10:15	9.8	20	0.28	alum	20	0.5		7	4
(Tuesday)	15:10	9.8	20	0.28	alum	20	0.5		7	7
	21:00	9.8	20	0.28	alum	20	0.5		9	9
December 15	12:00	9.8	20	0.28	alum	20	0.5	26	7	7
(Wednesday)	15:00	9.8	20	0.28	alum	20	0.5	26	7	7
	16:30	9.8	20	0.28	alum	20	0.5	26	6	7
December 16	10:00	9.8	20	0.28	alum	20	0.5	22		
	12:10	9.8	20	0.28	alum	20	0.5	22	7	7
(Thursday)	15:10	9.8	20	0.28	alum	20	0.5	22	7	5
	17:45	9.8	20	0.28	alum	20	0.5	22	7	7
December 17	00:45	9.8	20	0.28	alum	20	0.5	22	7	7
(Friday)	09:50	9.8	20	0.28	alum	20	0.5		5	5
	10:00	9.8	20	0.28	alum	20	0.5	22		
	12:00	9.8	20	0.28	alum	20	0.5		8	5
	14:00	9.8	20	0.28	alum	20	0.5	24	5	7
December 18	13:00	9.8	20	0.28	alum	20	0.5		5	4
(Saturday)		9.8	20	0.28	alum	20	0.5		5	5
December 19	12:30	9.8	20	0.28	alum	20	0.5	28	4	5
(Sunday)	15:00	9.8	20	0.28	alum	20	0.5		4	4
December 20	10:30	9.8	20	0.28	alum	20	0.5		4	5
(Monday)	15:00	9.8	20	0.28	alum	20	0.5		4	7
December 21		9.8	20	0.28	alum	20	0.5			
(Tuesday)		9.8	20	0.28	alum	20	0.5			
December 22	13:30	9.8	20	0.28	alum	20	0.5		8	7
(Wednesday)	16:30	9.8	20	0.28	alum	20	0.5	25	8	7
December 23	8:50	9.8	20	0.28	alum	20	0.5	25	5	5
(Thursday)	12:00	9.8	20	0.28	alum	20	0.5		10	11
AVERAGE								26	6	6

Notes:
- * *9.8 gpm/sq.ft. ≡ 3.4 gpm hydraulic filter loading*
- ♦ *lab duplicate*
- ♦♦ *filter duplicate*
- ** *projected lamella area*

Constant flocculation volume is 400 gallons

TABLE 3.14
SUMMARY OF DEMONSTRATION TEST RESULTS

	METHOD DETECTION LIMIT	Post-BMP ENR Influent				Post-STA ENR Effluent			
		I1	C1	F1A	F1B	I2	C2	F2A	F2C
Alkalinity (mg/L as $CaCO_3$)	**1.0**	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*
Mean		129	38	45	43	220	114	133	114
Max		203	66	68	68	244	132	200	128
Min		106	12	28	26	210	100	104	100
N		13	5	5	5	9	4	5	5
S.D.		26	21	17	18	12	15	38	11
Aluminum	**0.05**	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*
Mean		0.82	0.06	0.05	0.05	0.12	1.0	0.63	0.49
Max		0.96	0.08	0.05	0.05	0.40	1.6	1.2	1.1
Min		0.57	0.05	0.05	0.05	0.05	0.61	0.35	0.13
N		7	4	5	5	8	7	7	7
S.D.		0.17	0.01	0	0	0.14	0.32	0.33	0.33
Ammonia	**0.01**	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*
Mean		0.045	0.089	0.081	0.087	0.036	0.028	0.028	0.027
Max		0.078	0.120	0.110	0.120	0.057	0.032	0.034	0.037
Min		0.010	0.046	0.041	0.034	0.023	0.021	0.025	0.021
N		7	5	6	5	8	5	5	6
S.D.		0.026	0.029	0.024	0.033	0.012	0.005	0.004	0.006
Boron	**5.0**	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*
Mean		61	64	65	65	96	95	94	93
Max		67	71	75	74	108	105	106	102
Min		53	56	56	56	91	90	89	89
N		6	5	5	5	7	5	5	5
S.D.		5	5	7	6	6	6	8	5

TABLE 3.14
SUMMARY OF DEMONSTRATION TEST RESULTS

	METHOD DETECTION LIMIT	Post-BMP ENR Influent				Post-STA ENR Effluent			
		I1	C1	F1A	F1B	I2	C2	F2A	F2C
Calcium	0.10	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*
Mean		46	47	48	47	69	68	68	67
Max		51	48	50	49	78	77	78	75
Min		39	44	45	45	64	65	62	63
N		6	5	5	5	7	5	5	5
S.D.		4	2	2	2	5	5	6	4
Chloride	0.20	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*
Mean		64	146	148	148	151	150	150	152
Max		77	190	190	190	180	180	180	180
Min		52	130	130	130	140	140	140	140
N		6	5	5	5	7	5	5	5
S.D.		9	25	25	25	15	17	17	16
Cobalt	0.70	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*
Mean		0.7	0.8	0.9	0.9	0.7	0.7	0.7	0.7
Max		0.7	1.2	1.1	1.2	0.7	0.7	0.7	0.7
Min		0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
N		6	5	5	5	7	5	5	5
S.D.		0	0.2	0.1	0.2	0	0	0	0
Copper	2.0	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*
Mean		2.1	4.2	3.9	4.0	2.6	2.1	2.0	2.0
Max		2.3	5.2	5.0	4.8	6.0	2.7	2.0	2.0
Min		2.0	3.1	2.2	2.9	2.0	2.0	2.0	2.0
N		6	5	5	5	7	5	5	5
S.D.		0.1	0.8	1.2	0.8	1.5	0.3	0	0

TABLE 3.14
SUMMARY OF DEMONSTRATION TEST RESULTS

	METHOD DETECTION LIMIT	Post-BMP ENR Influent				Post-STA ENR Effluent			
		I1	C1	F1A	F1B	I2	C2	F2A	F2C
Iron	**0.01**	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*
Mean		2.2	0.81	0.29	0.23	0.07	0.12	0.11	0.10
Max		8.9	1.2	1.2	0.33	0.321	0.17	0.16	0.14
Min		0.9	0.62	0.05	0.17	0.012	0.07	0.06	0.05
N		8	5	8	5	9	5	3	5
S.D.		2.7	0.21	0.40	0.07	0.10	0.04	0.05	0.03
Lead	**2.0**	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*
Mean		2.2	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Max		2.3	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Min		2	2.0	2.0	2.0	2.0	2.0	2.0	2.0
N		2	2	2	2	2	2	2	2
S.D.		0.21	0	0	0	0	0	0	0
Magnesium	**0.012**	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*
Mean		13	13	13	13	21	20	20	20
Max		15	14	14	14	24	24	25	24
Min		11	11	12	12	18	19	18	18
N		6	5	5	5	7	5	5	5
S.D.		1.2	0.9	0.9	0.8	2.4	2.2	2.6	2.1
Manganese	**0.25**	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*
Mean		19	129	128	128	4.9	4.4	4.4	4.4
Max		26	171	175	171	5.9	4.9	4.9	5.0
Min		12	104	101	101	3.3	3.6	3.8	3.6
N		6	5	5	5	7	5	5	5
S.D.		5.1	27	30	28	0.9	0.5	0.5	0.5

TABLE 3.14
SUMMARY OF DEMONSTRATION TEST RESULTS

	METHOD DETECTION LIMIT	Post-BMP ENR Influent				Post-STA ENR Effluent			
		I1	C1	F1A	F1B	I2	C2	F2A	F2C
Mercury	**0.10**	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*
Mean		0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Max		0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Min		0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
N		6	5	5	5	7	5	5	5
S.D.		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Molybdenum	**1.0**	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*
Mean		1.4	1.1	1.1	1.1	1.2	1.1	1.4	1.4
Max		2.0	1.4	1.3	1.4	1.7	1.5	2.0	1.6
Min		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
N		6	5	5	5	7	5	5	5
S.D.		0.37	0.17	0.13	0.18	0.25	0.22	0.39	0.26
Nickel	**1.3**	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*
Mean		1.3	5.65	5.95	5.2	1.3	1.3	1.3	1.3
Max		1.3	6.4	6.8	6	1.3	1.3	1.3	1.3
Min		1.3	4.9	5.1	4.4	1.3	1.3	1.3	1.3
N		2	2	2	2	2	2	2	2
S.D.		0	1.1	1.2	1.1	0	0	0	0
NO_2NO_3-N	**0.004**	*mg N/L*	*mg N/L*	*mg N/L*	*mg/L*	*mg N/L*	*mg N/L*	*mg N/L*	*mg N/L*
Mean		0.54	0.53	0.56	0.55	0.06	0.06	0.06	0.06
Max		0.58	0.56	0.59	0.59	0.08	0.08	0.07	0.08
Min		0.49	0.49	0.52	0.52	0.04	0.05	0.05	0.05
N		6	5	5	5	7	5	5	5
S.D.		0.03	0.03	0.03	0.03	0.01	0.01	0.01	0.01

TABLE 3.14
SUMMARY OF DEMONSTRATION TEST RESULTS

	METHOD DETECTION LIMIT	Post-BMP ENR Influent				Post-STA ENR Effluent			
		I1	C1	F1A	F1B	I2	C2	F2A	F2C
Potassium	**0.01**	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*
Mean		5.0	5.2	5.2	5.2	8.3	8.2	8.2	8.1
Max		5.5	5.8	5.9	5.9	9.3	9.2	9.4	9.0
Min		4.5	4.7	4.8	4.8	7.8	7.9	7.7	7.8
N		6	5	5	5	7	5	5	5
S.D.		0.4	0.5	0.4	0.4	0.6	0.5	0.7	0.5
Reactive Silica	**0.30**	*mg SiO2/L*	*mg SiO2/L*	*mg SiO2/L*	*mg SiO2/L*	*mg SiO2/L*	*mg SiO2/L*	*mg SiO2/L*	*mg SiO2/L*
Mean		13	12	12	12	15	13	13	13
Max		15	14	14	14	18	17	16	17
Min		12	11	11	11	13	12	12	12
N		6	5	5	5	7	5	5	5
S.D.		1.1	1.2	1.2	1.2	2.2	2.2	1.6	2.1
Selenium	**3.0**	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*
Mean		3.7	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Max		7.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Min		3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
N		6	5	5	5	7	5	5	5
S.D.		1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sodium	**0.30**	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*
Mean		40	50	50	50	103	101	101	99
Max		53	65	66	64	121	118	119	115
Min		31	39	39	39	93	95	91	93
N		6	5	5	5	7	5	5	5
S.D.		8	10	11	10	12	10	11	9

TABLE 3.14
SUMMARY OF DEMONSTRATION TEST RESULTS

	METHOD DETECTION LIMIT	Post-BMP ENR Influent				Post-STA ENR Effluent			
		I1	C1	F1A	F1B	I2	C2	F2A	F2C
Sulfate	**0.20**	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*
Mean		36	39	39	39	50	164	166	166
Max		39	44	43	44	62	200	200	200
Min		33	35	36	35	43	140	150	150
N		6	5	5	5	7	5	5	5
S.D.		1.9	3.4	2.9	3.9	7.4	23	21	21
TKN	**0.06**	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*
Mean		1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Max		2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Min		1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
N		7	7	7	7	7	7	7	7
S.D.		0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Total Dissolved Solids	**0.50**	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*
Mean		308	357	353	354	581	587	596	579
Max		343	423	433	412	688	705	698	707
Min		278	303	298	288	524	537	551	533
N		6	5	5	5	7	5	5	5
S.D.		23	44	50	44	59	71	61	75
Total Organic Carbon	**2.75**	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*
Mean		18	8.0	7.2	8.0	29	17	13	11
Max		30	14	14	20	37	30	14	13
Min		4.5	4.4	4.4	4.1	13	12	12	3.9
N		13	5	5	5	9	5	5	5
S.D.		5.6	3.5	3.9	6.7	6.6	7.7	1.1	3.8

TABLE 3.14
SUMMARY OF DEMONSTRATION TEST RESULTS

	METHOD DETECTION LIMIT	Post-BMP ENR Influent				Post-STA ENR Effluent			
		I1	C1	F1A	F1B	I2	C2	F2A	F2C
Total Suspended Solids	**0.50**	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*
Mean		27	0.8	0.5	0.5	5	3.3	0.7	0.7
Max		68	1.1	0.5	0.5	21	4.0	1.2	0.8
Min		11	0.5	0.5	0.5	0.6	2.4	0.5	0.6
N		11	3	3	3	7	3	3	3
S.D.		17	0.3	0	0	7.8	0.8	0.4	0.1
Vanadium	**0.50**	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*
Mean		3.2	0.5	0.5	0.5	0.5	4.4	4.2	4.0
Max		3.5	1	0.5	0.5	0.5	5.0	5.1	4.7
Min		2.7	0.5	0.5	0.5	0.5	3.3	3.5	3.3
N		6	5	5	5	7	5	5	5
S.D.		0.3	0	0	0	0	0.68	0.58	0.50
Zinc	**10.0**	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*	*ug/L*
Mean		10	10	10	10	10	10	10	10
Max		10	10	10	10	10	10	10	10
Min		10	10	10	10	10	10	10	10
N		6	5	5	5	7	5	5	5
S.D.		0.0	0.0	0	0	0	0	0	0

Notes: 1. Nitrogen forms reported as mg/L as N.
2. I1 = Influent samples at the Post-BMP (North Test) Site.
C1 = Clarifier effluent samples at the Post-BMP (North Test) Site.
F1A = 'GE' filtrate samples at the Post-BMP (North Test) Site.
F1B = 'Swiss' filtrate samples at the Post-BMP (North Test) Site.
I2 = Influent samples at the Post-STA (South Test) Site.
C2 = Clarifier effluent samples at the Post-STA (South Test) Site.
F2A = 'Swiss' filtrate samples at the Post-STA (South Test) Site.
F2C = 'GE' filtrate samples at the Post-STA (South Test) Site.

TABLE 3.15
Analytical Field Data - Demonstration Testing Summary

	Post-BMP ENR Influent				Post-STA ENR Effluent			
	I1	C1	F1A	F1B	I2	C2	F2A	F2C
Color	*color units*	*color units*	*color units*	*color units*	*color units*	*color units*	*color units*	*color units*
Mean	153	22	12	13	113	69	61	64
Max	236	60	38	37	144	434	369	350
Min	82	<1	<1	<1	89	3	6	11
N	14	9	9	9	15	15	15	14
S.D.	42	21	14	13	18	142	118	119
Conductivity	*micro S*	*micro S*	*micro S*	*micro S*	*micro S*	*micro S*	*micro S*	*micro S*
Mean	578	625	616	625	1091	1083	1079	1076
Max	763	803	811	806	1465	1226	1228	1232
Min	456	529	540	539	919	952	955	954
N	17	11	11	11	17	17	17	16
S.D.	83	70	74	74	168	94	94	97
pH	*pH*	*pH*	*pH*	*pH*	*pH*	*pH*	*pH*	*pH*
Mean	6.8	6.0	6.0	6.0	7.1	6.4	6.4	6.5
Max	7.5	6.6	6.5	6.7	7.6	7.2	7.2	7.2
Min	6.2	5.7	5.6	5.4	6.5	5.8	5.8	5.8
N	17	12	12	13	18	18	18	17
S.D.	0.39	0.31	0.29	0.37	0.28	0.42	0.34	0.42
Turbidity	*NTU*	*NTU*	*NTU*	*NTU*	*NTU*	*NTU*	*NTU*	*NTU*
Mean	26	1.7	0.59	0.68	0.76	5.5	4.2	4.0
Max	53	6.1	2.3	2.2	1.9	24	21	21
Min	14	0.27	0.08	0.09	0.42	0.25	0.38	0.45
N	17	11	11	11	17	17	17	16
S.D.	10	2.0	0.76	0.73	0.40	8.5	7.1	6.9

Note: One color value (35) was deleted from the mean and considered an outlier.

TABLE 3.16

MEAN SFWMD LOW LEVEL MERCURY WATER QUALITY RESULTS

Test Site	Feed				Filtrate				Solids	
	THg UF	MeHg UF	THg F	MeHg F	THg UF	MeHg UF	THg F	MeHg F	THg UF	MeHg UF
North	6.176	0.132	0.883	0.052	0.306	0.045	0.313	0.048	81.06	0.861
South	1.352	0.045	0.578	0.045	0.500	0.045	0.400	0.045	7.994	0.113

Notes:

1. *All units in nanograms/liter (ng/L)*
2. *THg UF = total mercury unfiltered; MeHg UF = methyl mercury unfiltered; THg F = total mercury filtered; MeHg F = methyl mercury filtered*
3. *North Site feed total mercury filtered result from 12/20 (63.77 ng/L) appeared to be an outlier and was not used in calculating the mean.*

TABLE 3.17
TOXICITY AND AGP TESTING SUMMARY

Process	Test Date	Laboratory	Sample ID	Sample Description	Algal Growth Potential[1]	Chronic Tests: fish	Chronic Tests: waterflea	Chronic Tests: algae
DAF (Leopold)	10/26/99	FDEP	I1	North feed	51.091	IC20-41.4%	no effect	no effect
			F2-DAF	North filtrate	1.353	IC20-76.2%	no effect	no effect
ACTIFLO (Kruger)	11/15/99	FDEP	LK	South feed	0.306	no effect	no effect	no effect
			CLK	South filtrate	0.100	no effect	IC20-76.13%	no effect
CTSS	11/29/99	FDEP	096-I1	North feed	18.978	no effect	no effect	no effect
			096-F1A	North filtrate	0.100	no effect	IC20=73.4%[2]	no effect
			096-I2	South feed	0.116	no effect	no effect	no effect
			096-F2C	South filtrate	0.131	no effect	IC20-59.5%[2]	no effect
	12/7/99	FDEP	102-I2	South feed	0.102	no effect	no effect	no effect
			102-F2C	South filtrate	0.100	no effect	no effect	no effect
	12/7/99	Hydrosphere	102-I1	North feed	1[3]	significantly reduced survival	significantly reduced reproduction but not survival	significantly reduced growth
			102-F1A	North filtrate	-1[3]	no effect	no effect	no effect
MicroMag	12/9/99	Hydrosphere	MIT-I	South feed	no effect	no effect	no effect	no effect
			MIT-E	South filtrate	no effect	no effect	no effect	no effect
	12/21/99	Hydrosphere	MIT-I	North feed	no effect	significantly reduced survival and growth	significantly reduced reproduction but not survival	no effect
			MIT-E	North filtrate	no effect	significantly reduced survival and growth	no effect	no effect

Notes:
1. *Algal Growth Potential is in milligrams dry weight per liter.*
2. *IC20 is the concentration of sample which afffected reproduction in 20% of the population.*
3. *The laboratory control produced an average maximum standing crop (MSC) of 117 mg/L. Samples produced similar MSC's of -1 and 1 mg/L.*

TABLE 3.18
TOXICITY CHARACTERISTIC LEACHING PROCEDURE

TCLP Analysis - The Toxicity Characteristic Leaching Procedure (TCLP) is used to characterize wastes as hazardous or non-hazardous based on the Toxicity Characteristic Rule published in the Federal Register (40CFR 261.24) in 1990. The rule lists 39 toxic substances and maximum concentrations for each.

The table below lists the federal limits for the Toxicity Rule and the results of samples collected on December 14, 1999, from the North Test Site (Post-BMP) using ferric chloride and the South Test Site (Post-STA) using alum.

PARAMETERS	EPA METHOD REFERENCE	FEDERAL LIMITS (mg/L)	N.Sludge-Fe (mg/L)	S.Sludge-Al (mg/L)	REPORTING LIMIT (mg/L)
Metals (mg/L):					
Arsenic	6010	5.0	<0.04	<0.04	0.04
Barium	6010	100.0	0.75*	0.30	0.3
Cadmium	6010	1.0	<0.009	<0.009	0.009
Chromium	6010	5.0	<0.032	<0.032	0.032
Lead	6010	5.0	<0.050	<0.050	0.05
Mercury	245.1	0.2	<0.001	<0.001	0.001
Selenium	6010	1.0	<0.035	<0.035	0.035
Silver	6010	5.0	<0.010	<0.010	0.01
Volatiles (mg/L):					
Benzene	8260	0.5	<0.0002	<0.0002	0.0002
Carbon tetrachloride	8260	0.5	<0.0002	<0.0002	0.0002
Chlorobenzene	8260	100.0	<0.0002	<0.0002	0.0002
Chloroform	8260	6.0	<0.0002	<0.0002	0.0002
1,2-Dichloroethane	8260	0.5	<0.0002	<0.0002	0.0002
1,1-Dichloroethylene	8260	0.7	<0.0002	<0.0002	0.0002
Methyl ethyl ketone	8260	200.0			
Tetrachloroethylene	8260	0.7			
Trichloroethylene	8260	0.5	<0.0002	<0.0002	0.0002
Vinyl chloride	8260	0.2	<0.0005	<0.0005	0.0005
Semivolatiles (mg/L):					
o-Cresol	625/8270 mod.	200.00	<0.0025	<0.0027	0.0025, 0.0027**
m, p-Cresols	625/8270 mod.	200.00	<0.0025	<0.0027	0.0025, 0.0027**
1,4-Dichlorobenzene	625/8270 mod.	7.5	<0.0012	<0.0013	0.0012, 0.0013**
2,4-Dinitrotoluene	625/8270 mod.	0.13	<0.0012	<0.0013	0.0012, 0.0013**
Hexachlorobenzene	625/8270 mod.	0.130	<0.0012	<0.0013	0.0012, 0.0013**
Hexachlorobutadiene	625/8270 mod.	0.5	<0.0037	<0.004	0.0037, 0.004**
Hexachloroethane	625/8270 mod.	3.0	<0.0037	<0.004	0.0037, 0.004**
Nitrobenzene	625/8270 mod.	2.0	<0.0025	<0.0027	0.0025, 0.0027**
Pentachlorophenol	625/8270 mod.	100.0	<0.0037	<0.004	0.0037, 0.004**
Pyridine	625/8270 mod.	5.0	<0.0049	<0.0053	0.0049, 0.0053**
2,4,5-Trichlorophenol	625/8270 mod.	400.0	<0.0012	<0.0013	0.0012, 0.0013**
2,4,6-Trichlorophenol	625/8270 mod.	2.0	<0.0012	<0.0013	0.0012, 0.0013**
Pesticides (mg/L):					
Chlordane	8080	0.030	<0.0002	<0.0002	0.0002
Lindane	8080	0.4	<0.00001	<0.00001	0.00001
Methoxychlor	8080	10.0	<0.00005	<0.00005	0.00005
Toxaphene	8080	0.5	<0.00075	<0.00075	0.00075
Endrin	8080	0.02	<0.00005	<0.00005	0.00005
Heptachlor	8080	0.008	<0.00002	<0.00002	0.00002
Herbicides (mg/L):					
2,4-D	1311	10.0	<0.002	<0.002	0.002
2,4,5-TP (Silvex)	1311	1.0	<0.002	<0.002	0.002

*Notes: * Reported value is between the laboratory method detection limit and the laboratory practical quantitation limit.*

*** Different laboratory reporting limits - first listed limit is for "N.Sludge-Fe" and the second "S.Sludge-Al".*

TABLE 3.19
AVERAGE OF BACKWASH SOLIDS RESULTS

PARAMETER		Post-BMP ENR Influent		Post-STA ENR Effluent	
(mg/L) unless otherwise noted	***Method Detection Limit***	**F1A**	**F1B**	**F2A**	**F2C**
Total Phosphorus	0.004	0.18	0.20	0.09	0.04
Soluble Reactive Phosphorus	0.002	0.01	0.01	0.01	0.01
Total Dissolved Phosphorus	0.004	0.02	0.01	0.02	0.02
Total Suspended Solids	0.50	107	98	319	87
Total Organic Carbon	2.75	16	16	40	28
Alkalinity	1.0	67	68	175	132
Total Dissolved Solids	0.50	333	323	584	612
Sulfate	0.20	38	38	125	167
Reactive Silica (mg SiO2/L)	0.30	10	10	11	10
Chloride	0.20	121	124	147	150
Aluminum	0.05	0.84	0.91	22	18
Iron	0.01	34	26	1.9	1.0
Calcium	0.10	49	50	75	72
Magnesium	0.012	13	14	21	21
Potassium	0.01	5.0	5.1	8.5	8.3
Sodium	0.30	44	45	104	104
TKN	0.06	2.0	1.7	2.6	1.8
Nitrate/Nitrite (mg N/L)	0.004	0.37	0.39	0.06	0.06
Ammonia	0.01	0.08	0.08	0.04	0.03